NASA CR-188263

# SKETCHES FOR THE NATIONAL COMMISSION ON SPACE

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EEI -
REPORT NO. 85-107

**SKETCHES FOR THE NATIONAL COMMISSION ON SPACE**

1. Periodic station injection stage - places periodic station in the periodic orbit, (Engineer/Artist = 1/A)

2. Transfer stage - L1 or LEO to periodic orbit, periodic orbit to Phobos, (1/A)

3. Transfer stage - Phobos orbit to periodic orbit, periodic orbit to LEO or L1, (1/A)

4. Reusable, single stage propellant carrier, 30 MT, lunar surface to L1, (1/B)

5. Reusable, partially aerobraked single stage, fueled at both ends, cargo and people, Mars surface to Phobos, (1/B)

6. Shuttle II, (2/B)

7. Martian tricycle, Three-wheeled short-range scooter (TSS), (3/B)

8. Crane, (3/B)

9. Long Range Traverse Vehicle with wheels, (2 and 8/B)

10. Short Range Traverse Vehicle with loop wheels, (2 and 8/B)

11. Mars Bulldozer, (2 and 8/B)

12. $O_2$ plant on lunar surface (1,000 MT/year), 3 drum slusher scoop, fliudized bed reactor, heat recycling, (4/B)

13. Phobos plant for $H_2$ and $O_2$, (600 MT/year), rock melter 2 meter diameter drill, hydrolysis, all in a stack, (4/B)

14. Mars surface $O_2$ plant (300 MT/year) - seperates out $O_2$ from $CO_2$ in atmosphere, (4/B)

15. Zero g delta configuration for the Earth-Moon L1 spacebase with emphasis on the transportation node aspect, (5/A)

16. 1/3 g delta configuration for the Phobos transportation node/propellant plant with arriving vehicle from periodic station, (5/A)

17. 1/3 g delta configuration for the Earth-Mars periodic spacebase in an Earth pass-by with transfer vehicle in proximity operations, (5/A)

18. Alternate periodic station - Disk periodic station with boom to nuclear reactor, (5/B)

19. Electric propulsion cargo vehicle, (6 and 2/A)

20a. Mars base, (7/C)

20b. Preliminary Mars habitat, interior (7 and 10/ )

21. Mars airplane, (8/B)

22. Greenhouse, (9/C)

23. Reference configuration Space Station in LEO with Shuttle II approaching and alternate configuration periodic space station being assembled, (10/B)

24a. Beam builder, (4/B)

24b. Beam builder (10/ )

25a. Early lunar base layout (10/ )

25b. Shielding requirements (10/ )

26. Lunar derived construction material (10/ )

27. An interim lunar base (10/ )

28. Lunar radiotelescope (10/ )

29. Lunar astronomical telescope (10/ )

30. Short range EVA rover (10/ )

If more information is needed, the following individuals, associated with each sketch can provide it.

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ADDITIONAL SKETCHES

31. Mirror image periodic space station - one end, engineer - Barney Roberts, artist - Pat Rawlings

32. Mirror image periodic space station - full view, engineer - Barney Roberts, artist - Mark Dowman

33. Pressurized AOTV hangar for the mirror image periodic space station, engineer - Barney Roberts, artist - Pat Rawlings

34. Initial concept periodic station, engineer - Barney Roberts/Paul Phillips, artist - Mark Dowman

35. Explanation of periodic station operations, engineer - Gus Babb

36. Manned Mars base, painting and explanation - engineer - Eric Christiansen/Pat Rawlings, artist - Pat Rawlings

37. Second generation lunar base, engineer - Eric Christiansen/Pat Rawlings, artist - Pat Rawlings

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38. Personnel Carrier to the Libration Point Babb/Dowman

39. Variable-g Research Facility on LEO Space Station

40. Comparison of Hollister orbit-periodic space station scenario with conjunction class missions

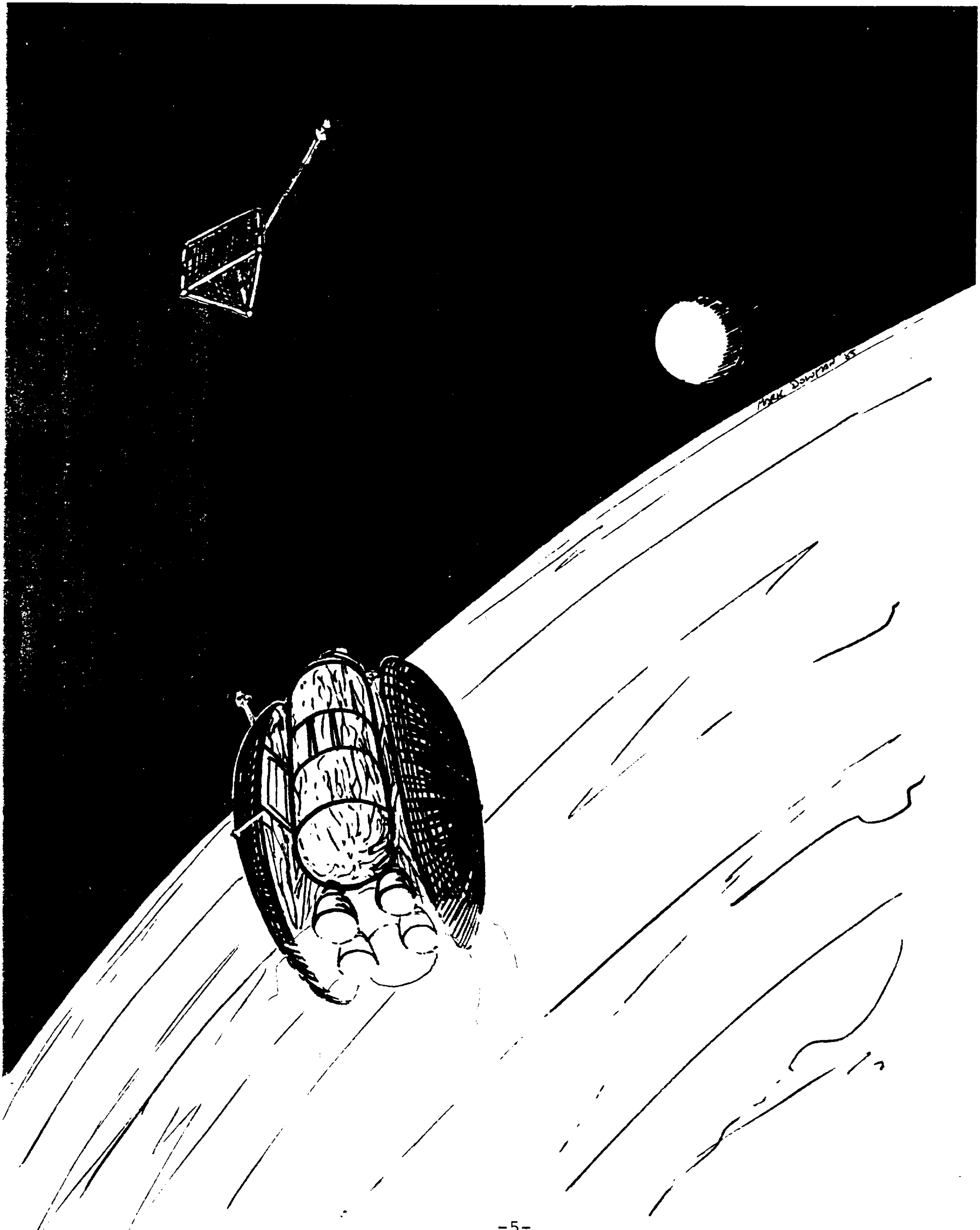
## PERIODIC STATION INJECTION STAGE

## SKETCH NO. 1

The injection stage is sized to inject a 100 m ton Periodic Space Station (PSS) into the periodic orbit. This is a one-time operation. The PSS then remains in the periodic orbit indefinitely.

It was assumed that the PSS enters the periodic orbit at the point where the Delta V's are lowest (generally moving away from Mars). This requires waiting several years until the PSS passes back by on a short leg to Mars before using it.

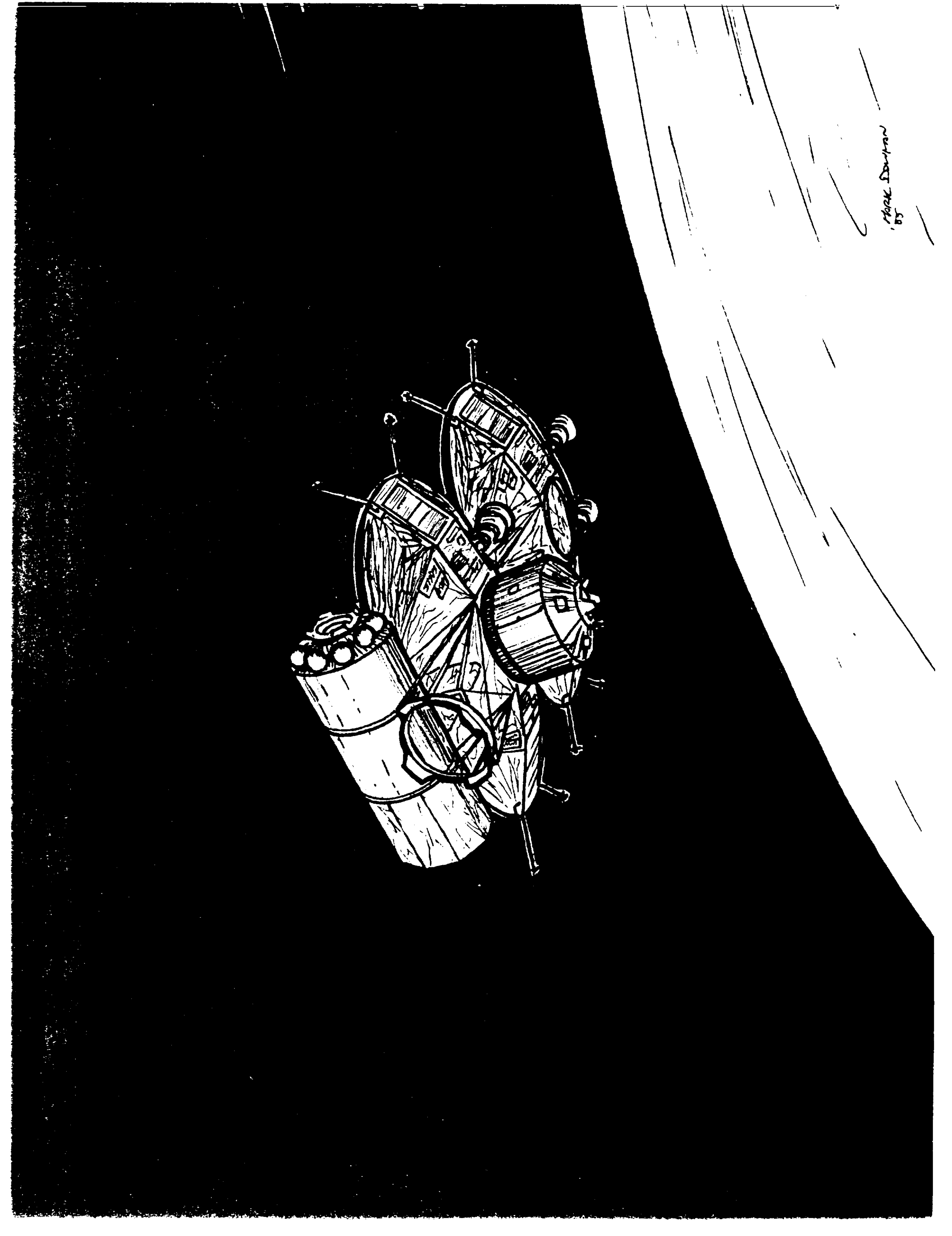
The PSS Injection Stage is composed of two (2) Aerobraking Orbital Transfer Vehicles (AOTV's) plus two auxiliary tanks. The individual AOTV's have performance characteristics equal to or surpassing those defined in previous AOTV studies conducted at JSC. The AOTV's are LOX/$LH_2$ stages with 42 m tons of propellant each and each weigh 7 tons at burnout. The two auxiliary tanks weigh 7.5 tons each and hold 75 tons of LOX/$LH_2$ each. The AOTV's are mounted parallel to each other with the auxiliary tanks between them so that both sets of AOTV engines can be used together. This raises the thrust to weight ratio above .1 so that g-losses do not get too high. The tanks need to be interconnected so that one AOTV and both auxiliary tanks are emptied while the remaining AOTV is still fueled. The empty AOTV and tanks are then separated and the second AOTV completes the insertion. The empty tanks and the first (separated) AOTV aerobrakes back to Low Earth Orbit. The second AOTV remains with the PSS for use later.



## CREW TRANSFER STAGE - EARTH TO PSS TO MARS

## SKETCH NO. 2

This stage transfers a crew module plus 10 tons of cargo for expendables to the PSS as it passes Earth heading toward Mars. Again, a 42 ton AOTV was used along with a 5 ton Manned Mission Module (MMM) described in previous work. The MMM provides habitation and life support for a crew being transported on an AOTV. For Earth to PSS transfer, two fueled AOTV's are stacked end to end. The first AOTV burns out and returns to LEO via aerobraking. The second AOTV docks with the PSS with propellant still remaining. The AOTV and MMM remains attached to the PSS until Mars is reached. The crew then enters the MMM again and leaves the PSS using the AOTV to aerobrake into a Mars orbit. The AOTV then uses its remaining propellant to rendezvous with Phobos for crew transfer and refueling.

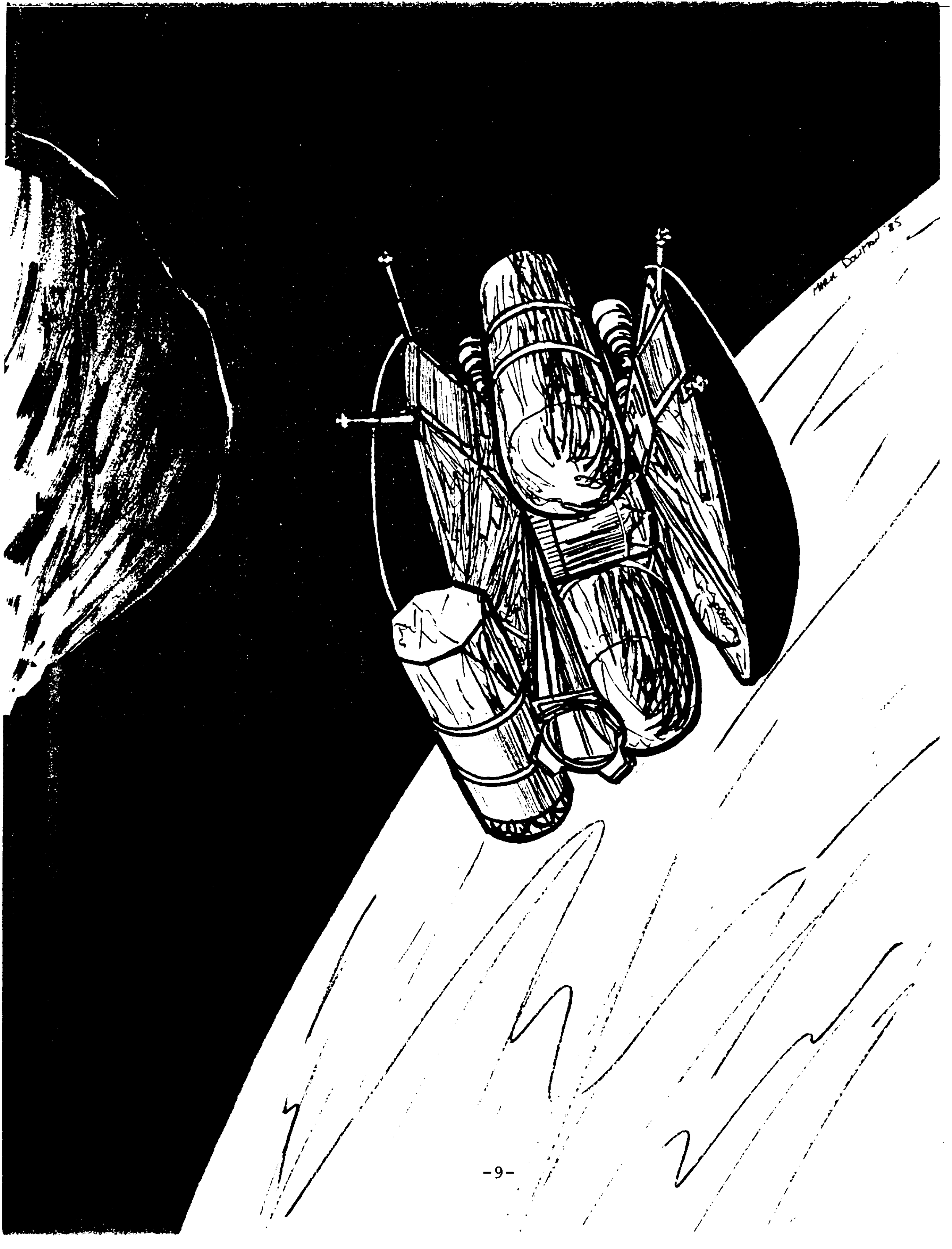

Mark Dowman '85

## CREW TRANSFER STAGES - MARS TO PSS TO EARTH

## SKETCH NO. 3

For crew transfer from Mars to the PSS, the AOTV and MMM that brought the crew from Earth are again utilized along with a second AOTV (permanently based at Mars) plus two of the 75 ton capacity auxiliary tanks. The configuration would be the same as for the PSS injection stage except that the payload is the crew in the MMM plus 10 tons of consumables.

Again, the first stage aerobrakes back to Mars' orbit for future reuse. The second stage docks with the PSS with some propellant remaining. At Earth, the crew reenters the MMM. The AOTV and MMM separate from the PSS for Earth orbit entry. The propellant in the AOTV (about 8 tons) is expended just before entry to slow the aeroentry speed down from 12,600 m/sec (41,300 fps) to about 10,700 m/sec (35,000 fps) so that aerocapture can be accomplished within heating and aeroload constraints. The OTV then rendezvous with the LEO Space Station for crew rotation to Earth.



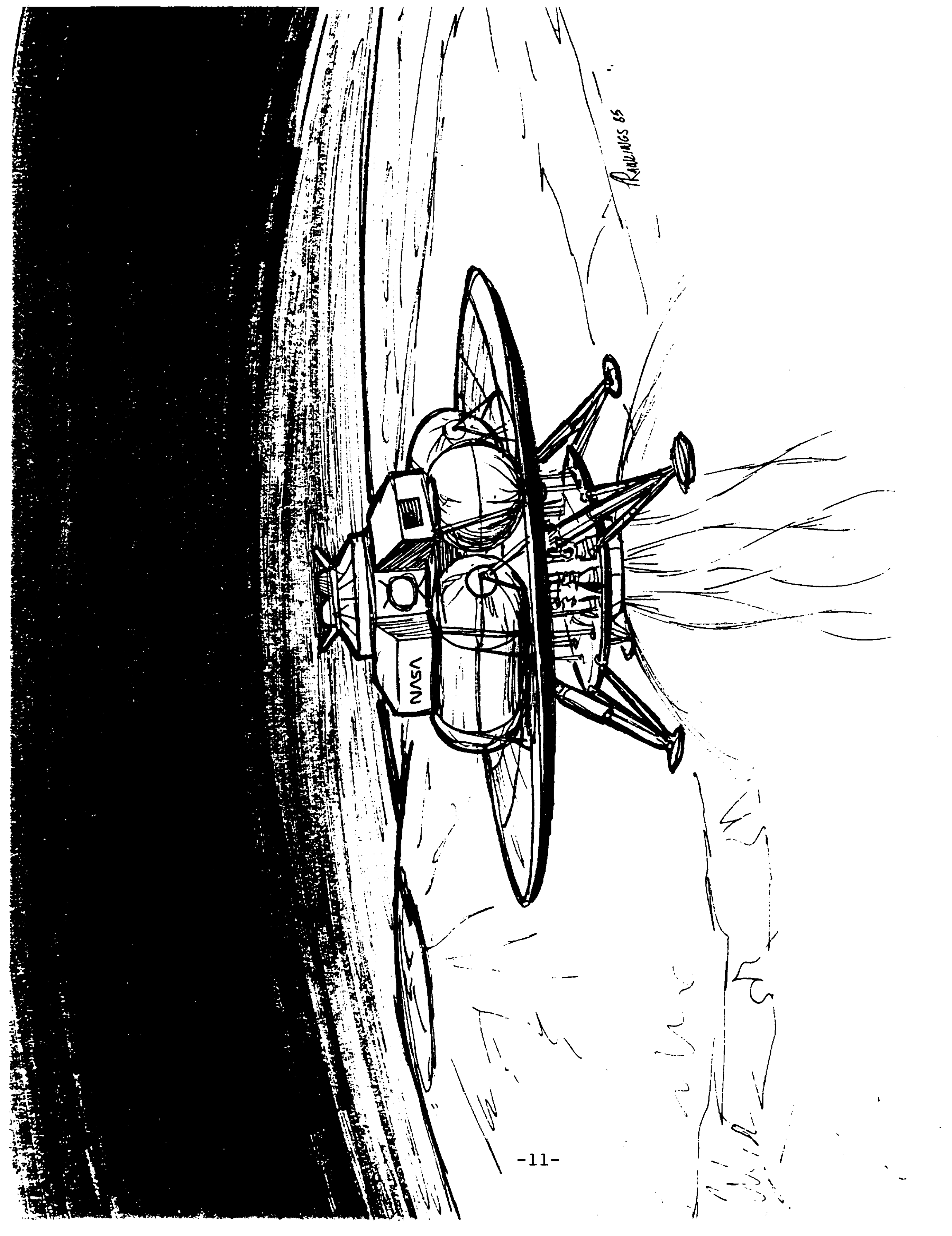
**MARS REUSABLE LANDER/LAUNCHER**

**SKETCH NO. 4**

The Mars reusable Lander/Launcher is loaded with propellants at Phobos and on the surface of Mars. This vehicle is designed to travel only from the martain surface to Phobos and back.

Two lander versions were considered, aerobraking and all propulsive. The aerobraking vehicle is shown in the sketch.

Aerobrake Weight = 7.1 tons (lift capability limit)
Propellant Weight = 45 tons
Burnout Weight = 15.0 tons (including aerobrake)
Payload Up = Manned Capsule
Payload Down = Manned Capsule + 20 tons
Aerobrake Diameter = 50 feet (15.24 meters)
Two $O_2$ tanks - 3.6 meter diameter spheres
Two $H_2$ tanks - 3.6 meter hemispherical ends with 1.7 meter cylindrical middle
Tank dimensions are inside diameter, add .3 meters of insulation all around.


NASA
RAWLINGS 85

## LUNAR LANDER/LAUNCHER

### SKETCH NO. 5

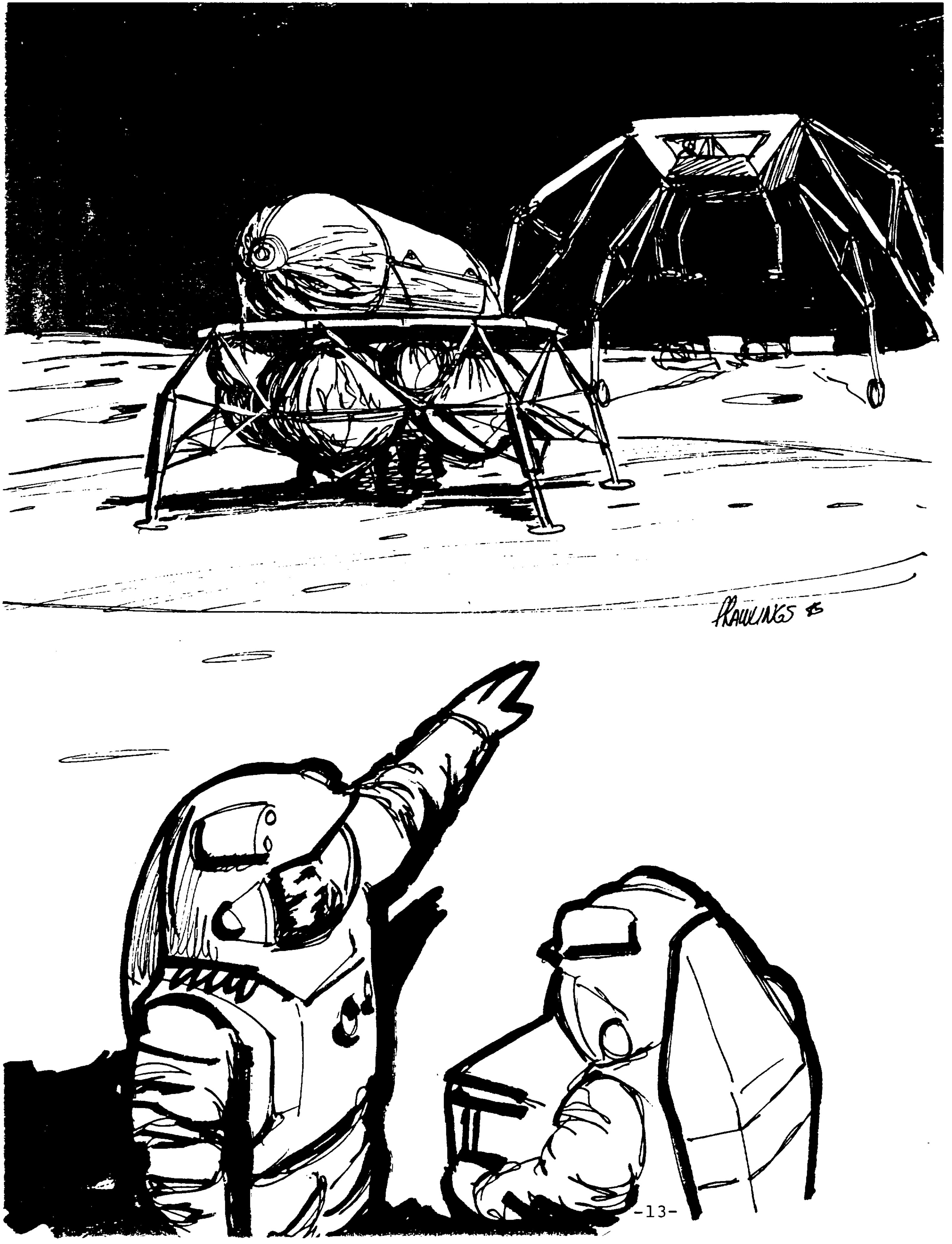
The reusable lunar lander/launcher is loaded with propellants only on the lunar surface and sized to deliver 30 tons of payload (propellant) from the lunar surface to the L1 point, returning to the lunar surface empty. The vehicle is an enlarged version of another lander defined in previous work.

Usable Propellant = 50 tons
Burn Out Weight = 8.6 tons
Payload to L1 from lunar surface, returning empty = 30 tons
Payload from L1 to lunar surface, launching empty = 15 tons

Isp = 460 seconds, $LO_2/H_2$
Mixture ratio = 7 to 1
Four $H_2$ tanks - 3.6 meter diameter spheres (89 cubic meters)
Four $O_2$ tanks - 2.9 meter diameter spheres (49 cubic meters)

All diameters are internal, add .3 meters of insulation all around.

Shown in background is an option for a cargo-transfer crane which off-loads payloads from the reusable landers and transports them to waiting trailers which are a safe distance from the landing area.


RAWLINGS 85

## SHUTTLE II

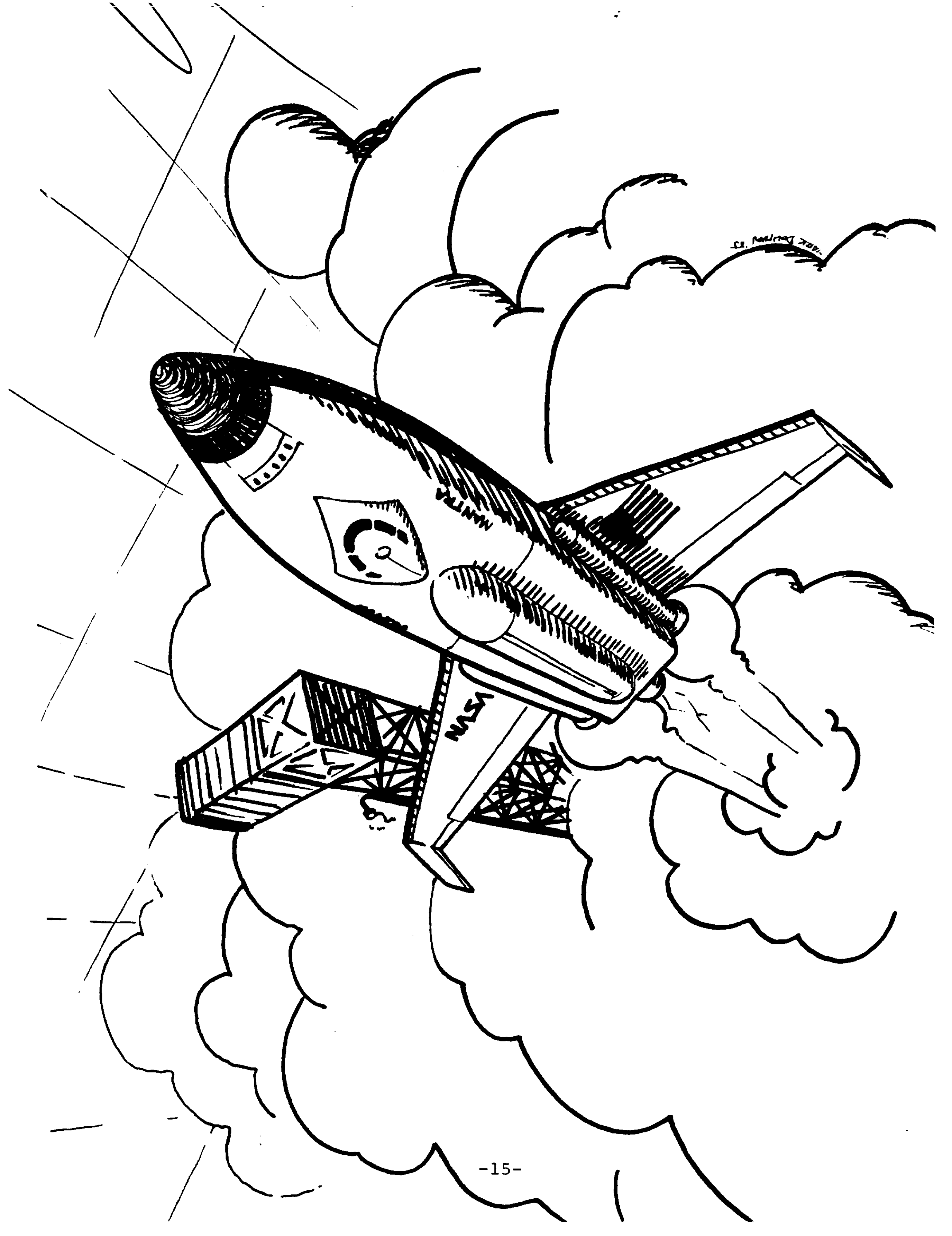
## SKETCH NO. 6

Sketch No. 6 illustrates a design concept for a second generation space shuttle known as Shuttle II. The core concept of this shuttle is an augmentable single stage to orbit, fully reusable launch vehicle. It has a delta wing configuration with tip fins and is meant for vertical take-off and horzontal landing. The Shuttle II airframe and aeroshell structures are integral with internal tankage. The payload bay is external to the vehicle and is changeable.

Without augmentation, Shuttle II can carry 20,000 pounds to a 270 nautical mile, $28.5^{o}$ orbit in its 15 foot by 30 foot external payload bay. Augmentation can be accomplished by a variety of boosters located near the base of the delta wings. For example, with two 120,000 pound solid rocket boosters, Shuttle II can carry 13,000 pounds of payload to a 150 nautical mile, $98^{o}$ orbit. The configuration shown in Figure 6 is augmented with solid rockets and uses a 15 foot by 60 foot long payload bay. The large payload bay is used for due east launches when augmentation allows payload weights in excess of the nominal 20,000 pounds.

Shuttle II is processed horizontally and erected at the launch pad. It has a size and dry mass approximately the same as a DC-10. The wing span is 148 feet and the length is 180 feet. This compares with the current Space Shuttle overall length of 183.5 feet and wing span of 78.1 feet.

The Shuttle II will require only a moderate amount of advanced technology and is planned to meet mission requirements in the post-2000 timeframe. It is intended to cover commercial and civilian government needs for high productivity, low cost service. Candidate missions include small, high priority payloads, personnel, high value products, satellite and platform servicing, and repair and rescue missions.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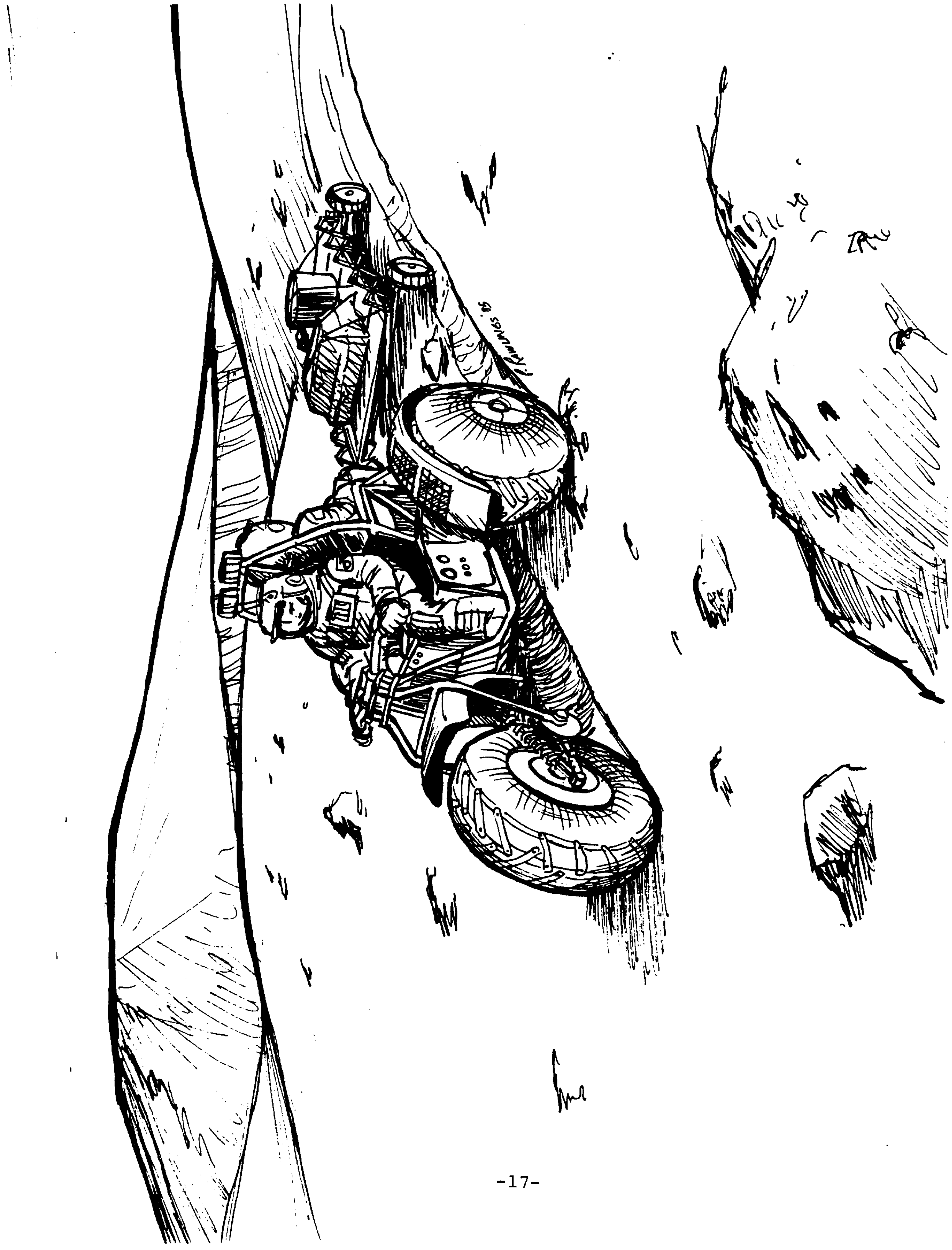
NASA

## THREE-WHEELED SHORT-RANGE SCOOTER (TSS)

### SKETCH NO. 7

A concept for a short-ranged manned vehicle suitable for light duty around the Mars Base is illustrated in Sketch No. 7. Due to its three-wheel design, the TSS has a low center of gravity for stable operations at 0-25 MPH. It is outfitted with a rumble seat for two-person operations and a stowable trailer (stored behind and under the rumble seat when not in use) for light supply/maintenance equipment transport capability. The TSS affords the driver a wide angle-of-view. Other safety features include a roll bar, headlights, front and rear shock absorbers, rearview mirror, and safety belts/shoulder harnesses. Power is provided by regenerable fuel cells that are recharged by loading $LO_2/LH_2$. Solar cells provide an auxiliary power source for communications and other critical systems. Mass of the TSS is estimated as 500 Kg including an aluminum frame body.



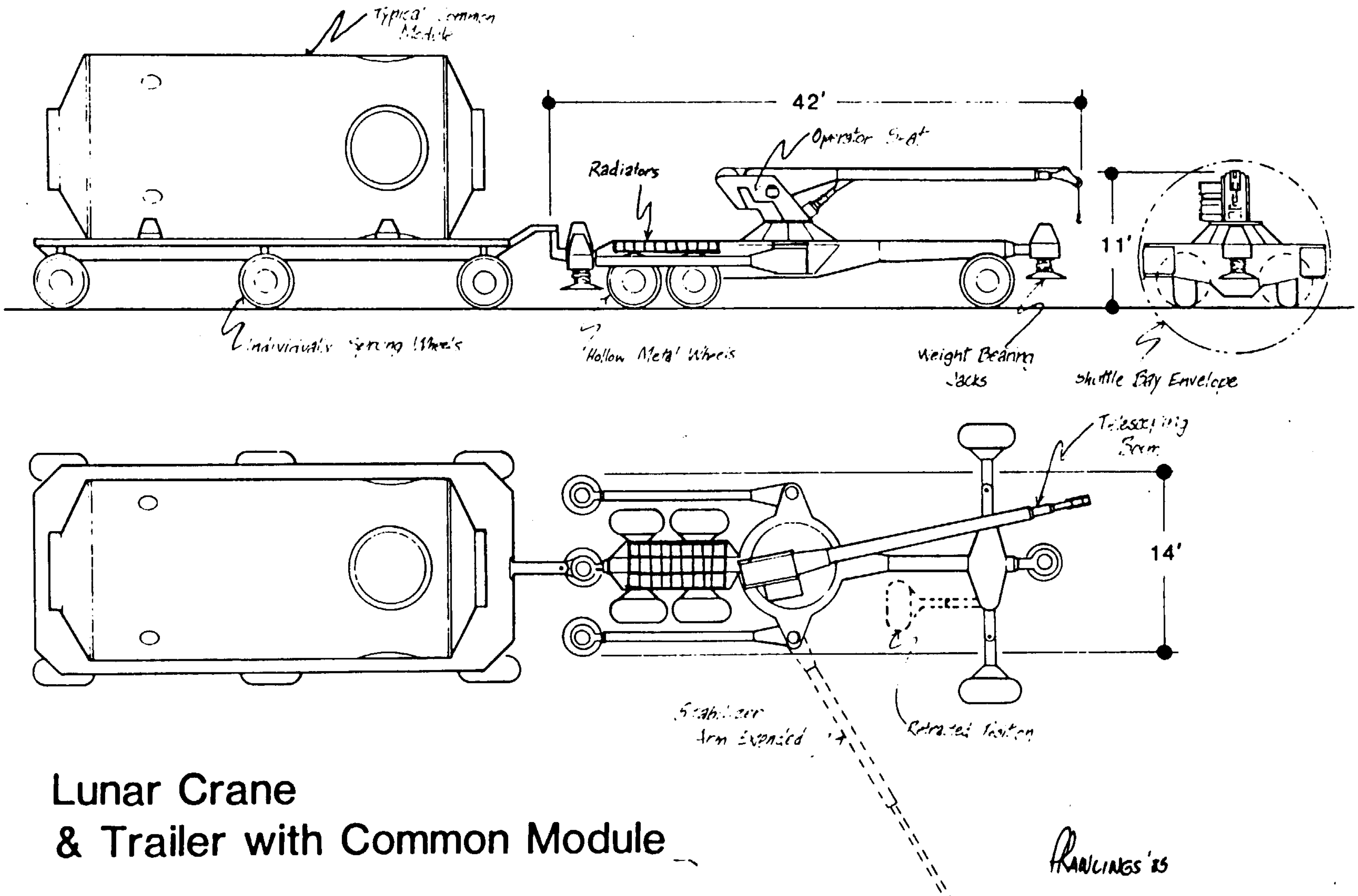
## LUNAR CRANE

## SKETCH NO. 8

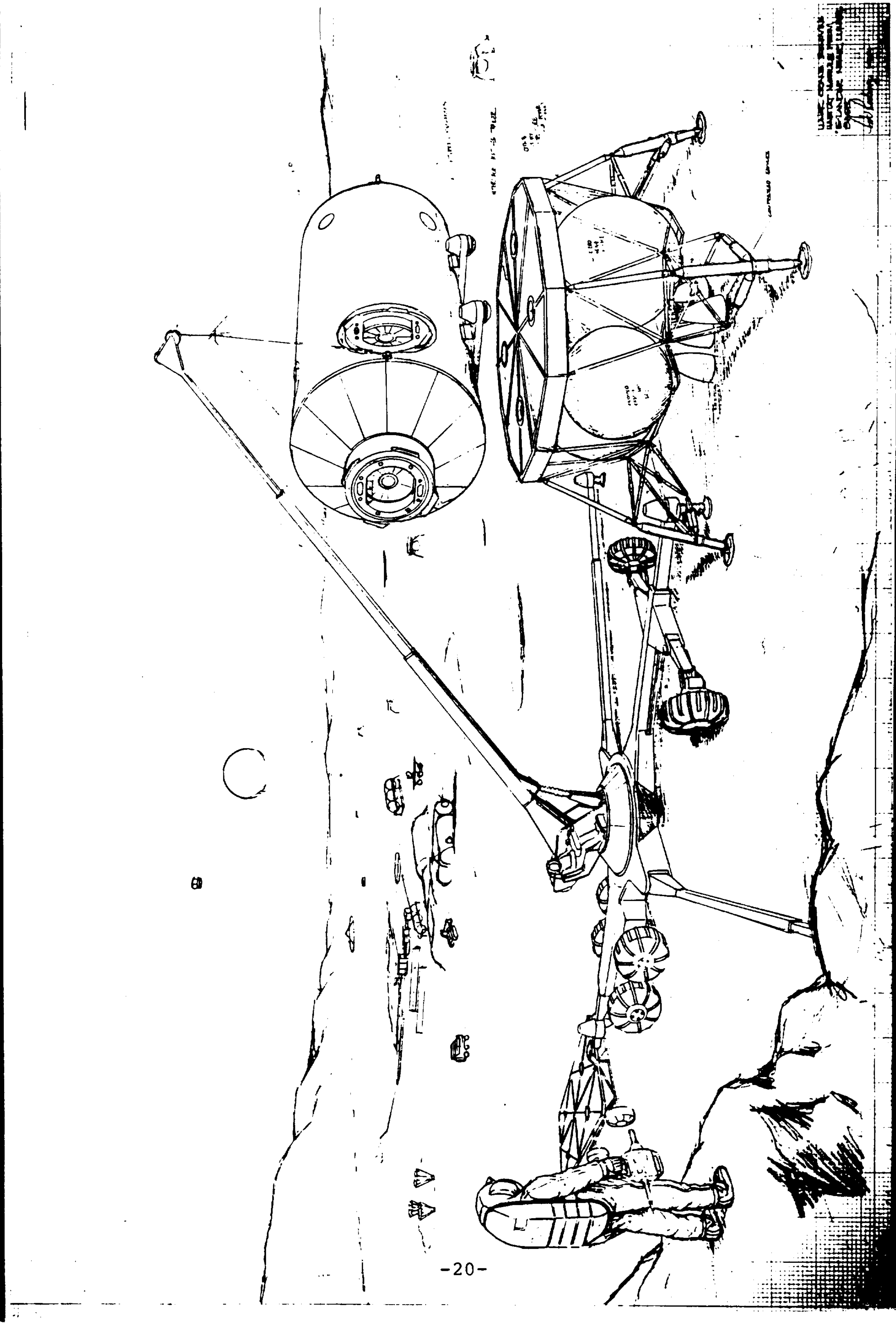
Sketch No. 8 shows a Lunar Crane pulling a common module on a trailer. This six wheeled crane is intended for general use in the vicinity of a lunar base. A similar configuration could be used on Mars although gravitation differences between the Moon and Mars would require substantial structural enhancements.

The Lunar Crane has two deployable stabilizers and one fixed stabilizer. These stabilizers use Acme threaded jacks to move the foot pads. The telescoping boom also uses Acme threads and the cable is winch operated. The need for hydraulics and ancillary hydraulic equipment is eliminated. The wheels are hollow metal and are driven by electric motors similar to the Apollo Lunar Rover Vehicle. A trailer hitch is provided at the back of the vehicle for towing cargo. The crane is operated by an astronaut seated near the base of the boom.

The crane itself is designed to fit within the current 4.5 meter by 11 meter Shuttle payload bay envelope. It has a mass of approximately 17.5 metric tons which is equivalent to the mass of one common module. Fully deployed in traveling configuration, the crane is 13 meters long, 3.3 meters high and 6 meters wide.




# Lunar Crane
# & Trailer with Common Module



## LONG RANGE TRAVERSE VEHICLE

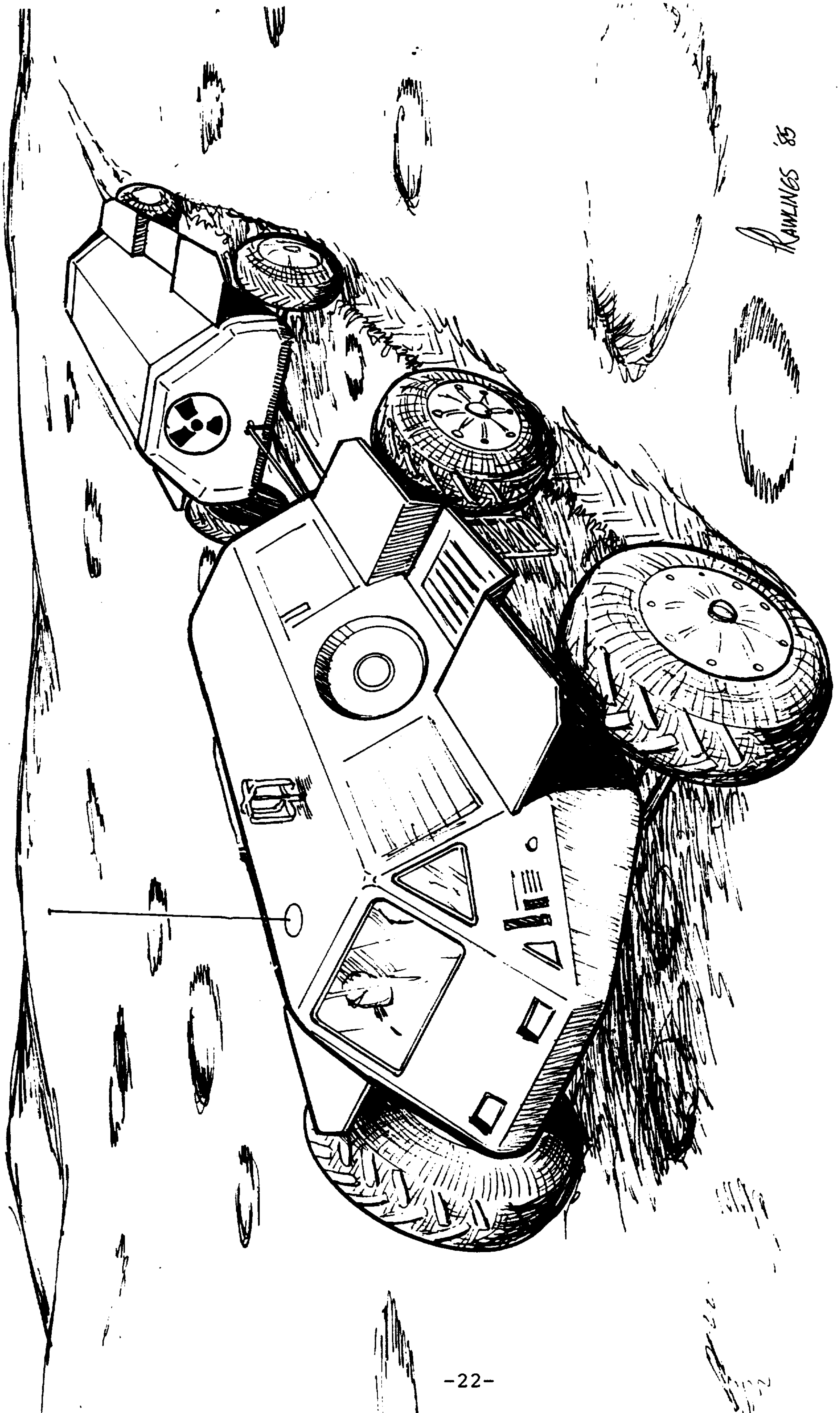
## SKETCH NO. 9

Sketch No. 9 illustrates a Long Range Mars Traverse Vehicle consisting of two fifteen foot long segments. The forward segment contains the habitable pressurized cabin. The control console and sleeping and working areas are located in the front section of this segment while the back section contains an airlock. The airlock is provided with shielding for solar flare protection and is outfitted as a safe haven zone. This segment also contains a secondary fuel cell power supply.

The trailing segment is dedicated entirely to a nuclear reactor for primary power generation. This 100 Kw reactor is required because of the length of the vehicle's mission and is assumed, for sizing purposes, to be an SP-100 type power supply. The trailing segment provides 15 square meters of radiators which will operate at $1300^{\circ}$ Kelvin. This power system is recognizably the largest single development item for the vehicle.

Locomotion is provided by four electrically powered wheels on each segment. Each 72 inch tall by 30 inch wide wheel is individually suspended and powered by electric motors similar to those used for the Lunar Rover Vehicle. The two segments are tied together by a multiply articulated connector. This configuration is known as an 8 x 8 semi-articulated vehicle.

The vehicle is designed to traverse from the Mars equator to one of its poles and back. This 7,000 mile trip will last approximately 80 days at an average speed of 15 miles per hour. Crew rest periods and exploration activities are included in this estimated time period. The length of this trip requires energy efficiency and low maintenance which is why wheels were chosen.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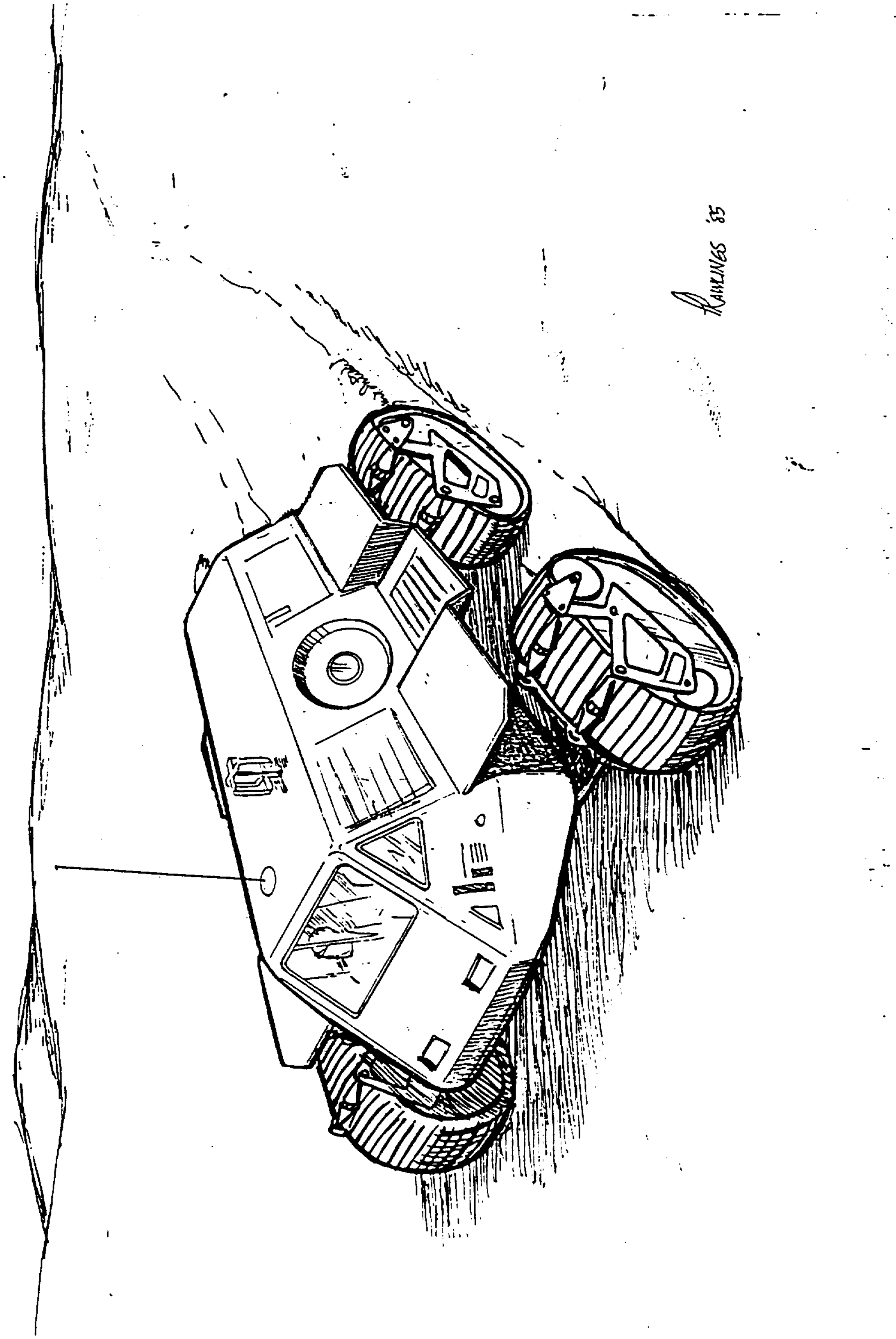
## SHORT RANGE TRAVERSE VEHICLE

## SKETCH NO. 10

Sketch No. 10 illustrates a Short Range Mars Traverse Vehicle consisting of one fifteen foot long segment. This segment contains the habitable pressurized cabin. The control console and sleeping and working areas are located in the front section while the back section contains an airlock. The airlock is provided with shielding for solar flare protection and is outfitted as a safe haven zone. A fuel cell power supply is used as the primary power supply. Locomotion is provided by four electrically powered elastic loopwheels.

The vehicle is designed for short range traverses in the vicinity of a Mars base. It is actually the front segment of the Long Range Mars Traverse Vehicle. The four wheels have been replaced by loopwheels to provide better obstacle clearing capabilities. The suspension system is designed to allow this change at the Mars base. Because of the short range of this vehicle, problems with loopwheel fatigue failure and maintenance can be neglected.

The articulated connector used for the nuclear power supply of the long range version can now serve as a trailer hitch for short range cargo hauling.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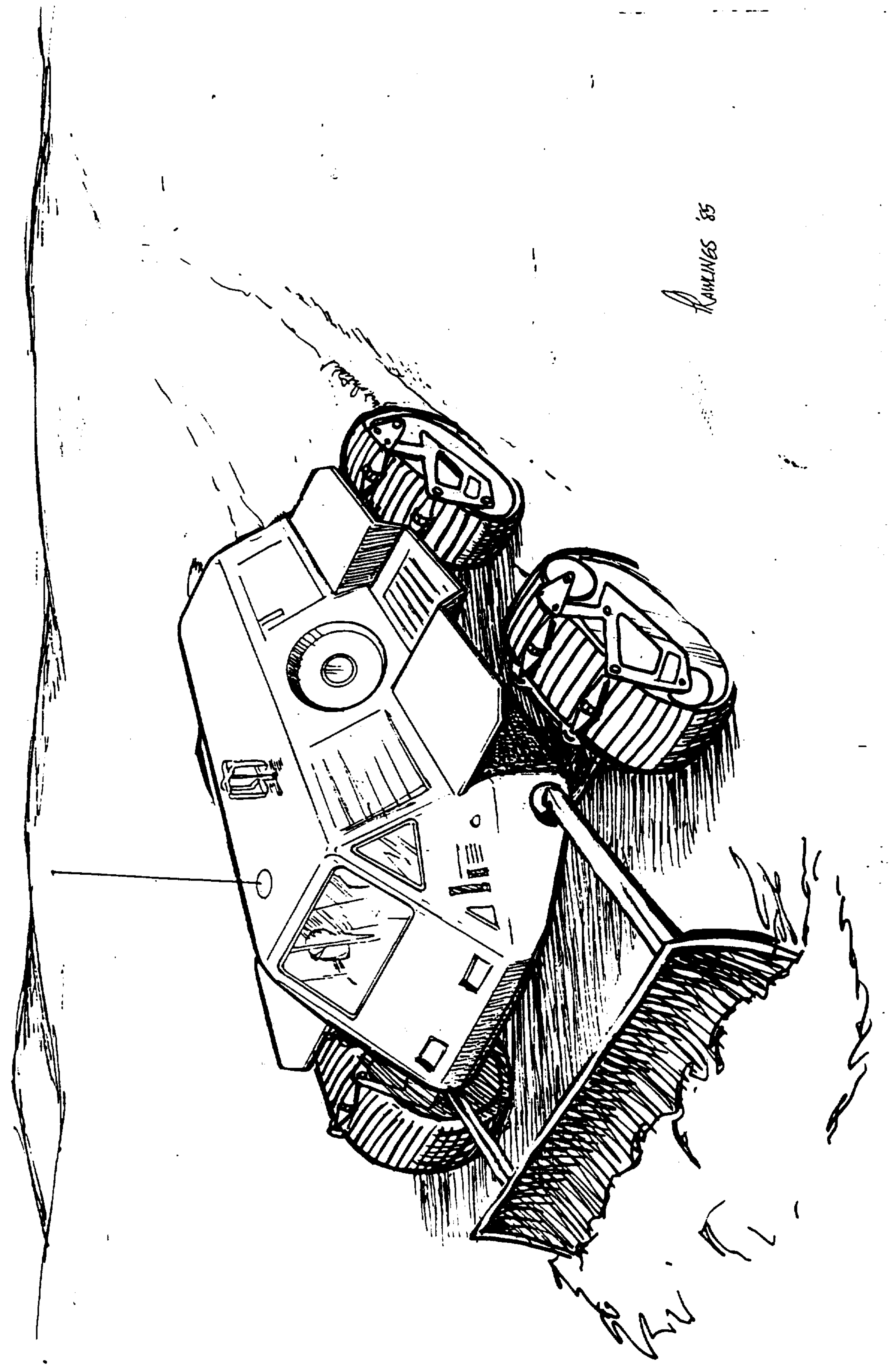
## MARS BULLDOZER

## SKETCH NO. 11

Sketch No. 11 illustrates a Mars Bulldozer. It is simply the Short Range Mars Traverse Vehicle fitted with a bulldozer blade. This vehicle can be used for general utility duties such as building roads and covering base modules with Martian soil and is intended for use in close proximity to the Mars base.

The bulldozer fitting is shown to illustrate the capability of the vehicle to perform multiple tasks while it is not being used for exploration. Other fittings such as front-end loaders and back-hoes can also be provided.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## LUNAR SURFACE OXYGEN PLANT

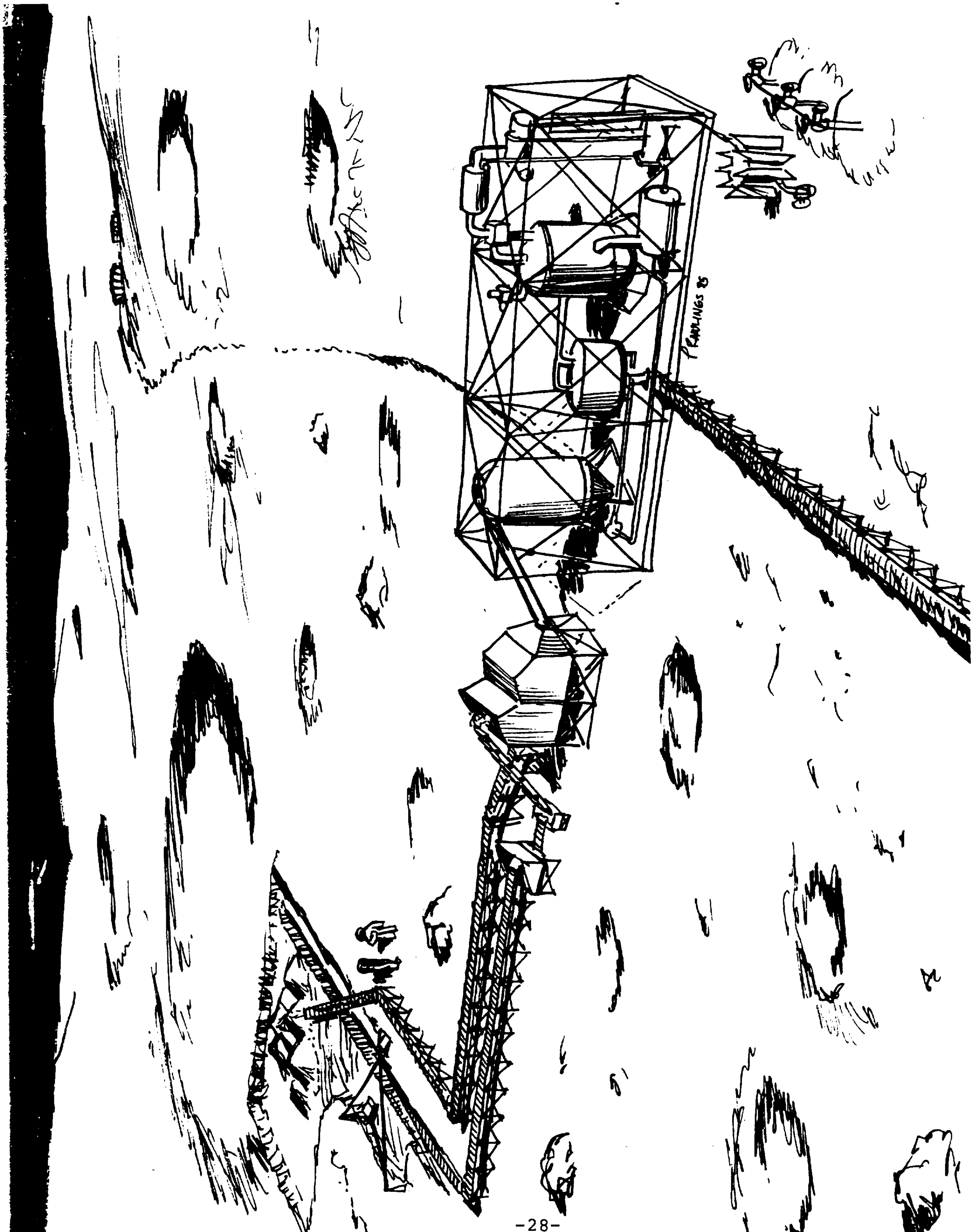
## SKETCH NO. 12

Sketch No. 12 illustrates a concept for a plant designed to produce 1,000 MT/year of liquid oxygen from lunar regolith material.

Powder-like undifferentiated lunar soil is collected by a 3-drum drag scraper machine and is transported by conveyor to a shaker screen to remove large diameter material. The screened lunar soil enters a two-stage electrostatic separation process to extract ilmenite. Over 90% of the soil is returned to a disposal site by conveyor. The separated ilmenite is stored in a silo to allow hold-up time before the later process steps.

A pneumatic conveying system continuously feeds ilmenite from the silo through a heat exchanger and into an 8 ft. diameter, 20 ft. high fluidized bed reactor. Hydrogen is injected into the bottom of the fluidized bed where it reacts with ilmenite to extract oxygen and form water vapor. The spent reactor solids are removed and used to preheat the reactor's ilmenite feed, then stockpiled for possible future use.

The water vapor from the reaction is stripped of dust in a cyclone separator and then split by electrolysis into oxygen and hydrogen. The hydrogen is recycled via a $H_2$ gas heater back to the reactor and pneumatic conveying system. The $O_2$ is fed through a heat exchanger (where it preheats makeup $LH_2$) to a liquefaction unit and then to well insulated (buried) liquid oxygen storage tanks. Power is supplied by nuclear reactors.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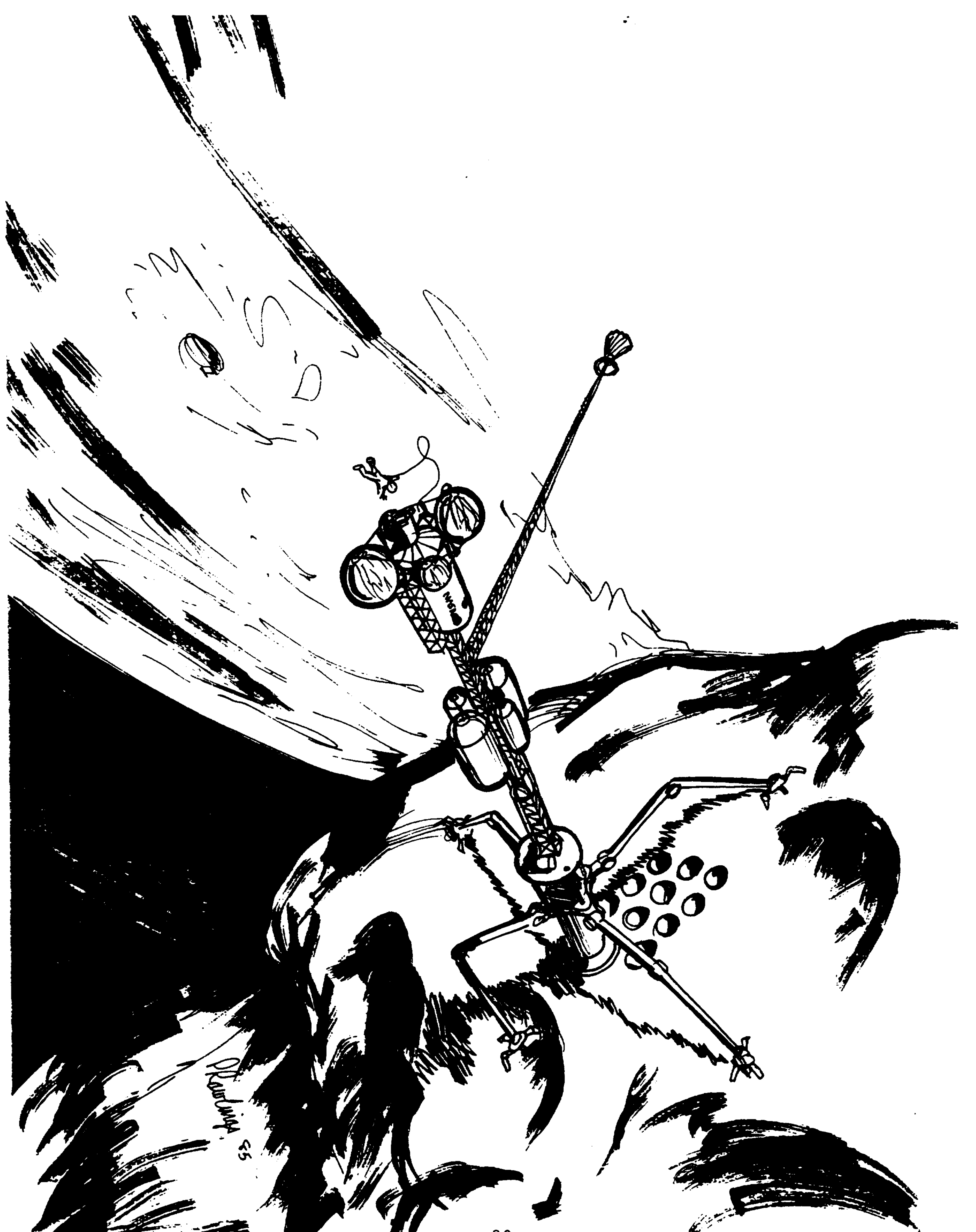
## $H_2$ AND $O_2$ PLANT ON PHOBOS

## SKETCH NO. 13

A concept for a plant designed to produce 600 MT/year of propellants (533 MT/year $LO_2$ and 67 MT/year $LH_2$) on Phobos is given in Sketch No. 13.

A 4 meter long by 2 meter diameter hole is bored into Phobos by a rock-melting machine utilizing a nuclear power system generating approximately 2 MW of thermal energy. About 5% of the carbonaceous chondritic material melted by the rock-melter is water vapor which flows out of the bore-hole through a filter (to remove CO, $CO_2$, $SO_2$, $H_2S$) and liquefied before electrolysis. The generated $O_2$ and $H_2$ gas is then liquefied and stored. Command/control of the unit is provided from a habitation module fitted with a docking mechanism. Periodic, short movements of the plant to bore a new hole are accomplished via legs (with end effectors) after hydraulic jacks have lifted the melting penetrator. Electric power for the process units is supplied by a nuclear generator located at the end of the lateral boom.

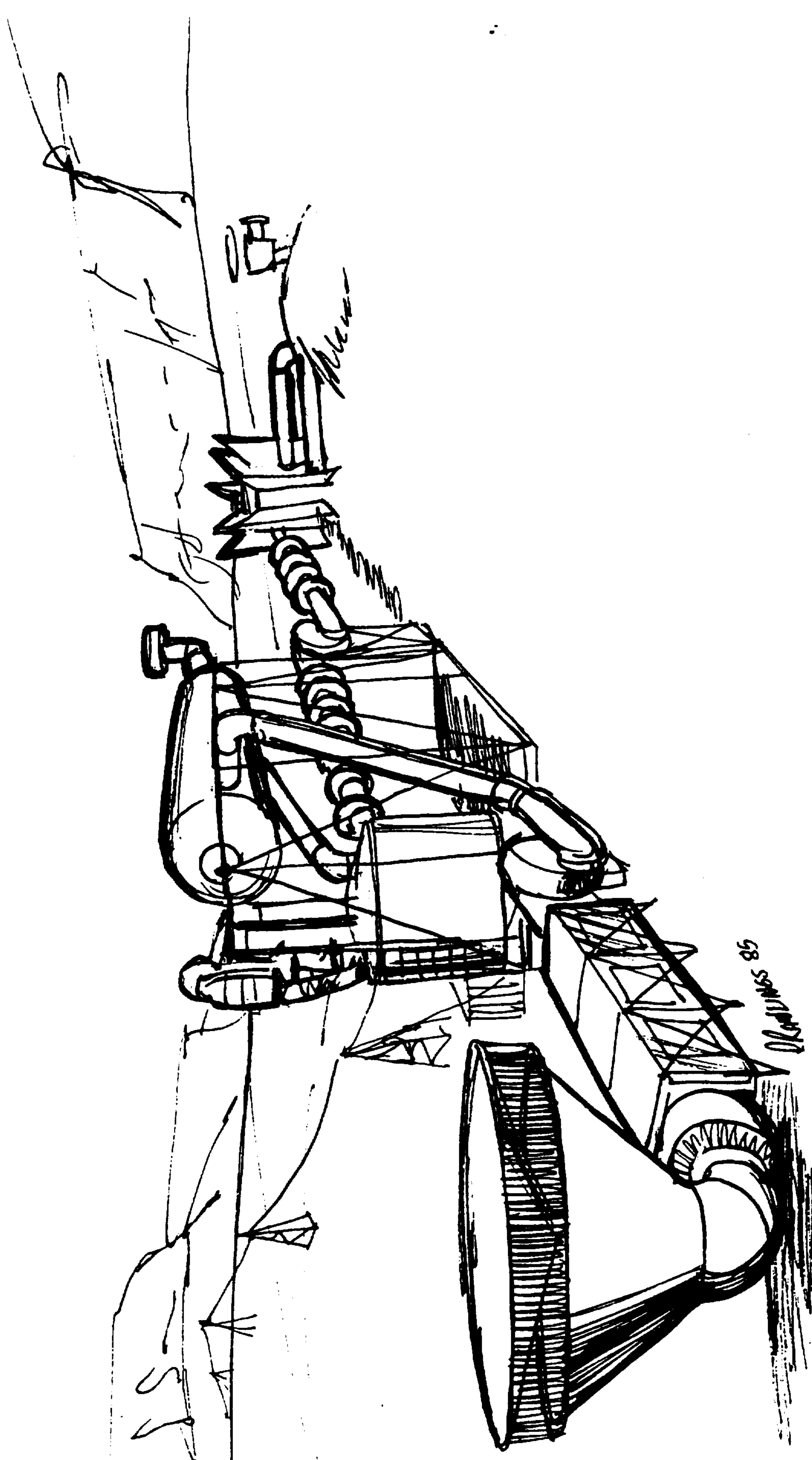


## MARS SURFACE $O_2$ PLANT

### SKETCH NO. 14

A concept for a plant designed to produce 300 MT/year of liquid oxygen from the Martian atmosphere is illustrated in Sketch No. 14.

Mars' atmosphere, which contains approximately 95% carbon dioxide, is first filtered to remove particulates. It is then compressed and preheated before entering an electrolytic unit operated at elevated temperature and pressure where some of the carbon dioxide is split into oxygen and carbon monoxide. The hot unused exhaust gas from this unit is utilized in a heat exchanger to preheat the inlet gas and is subsequently vented. The pure oxygen product from the unit is cooled via radiators, compressed and liquefied before being stored in buried tanks.

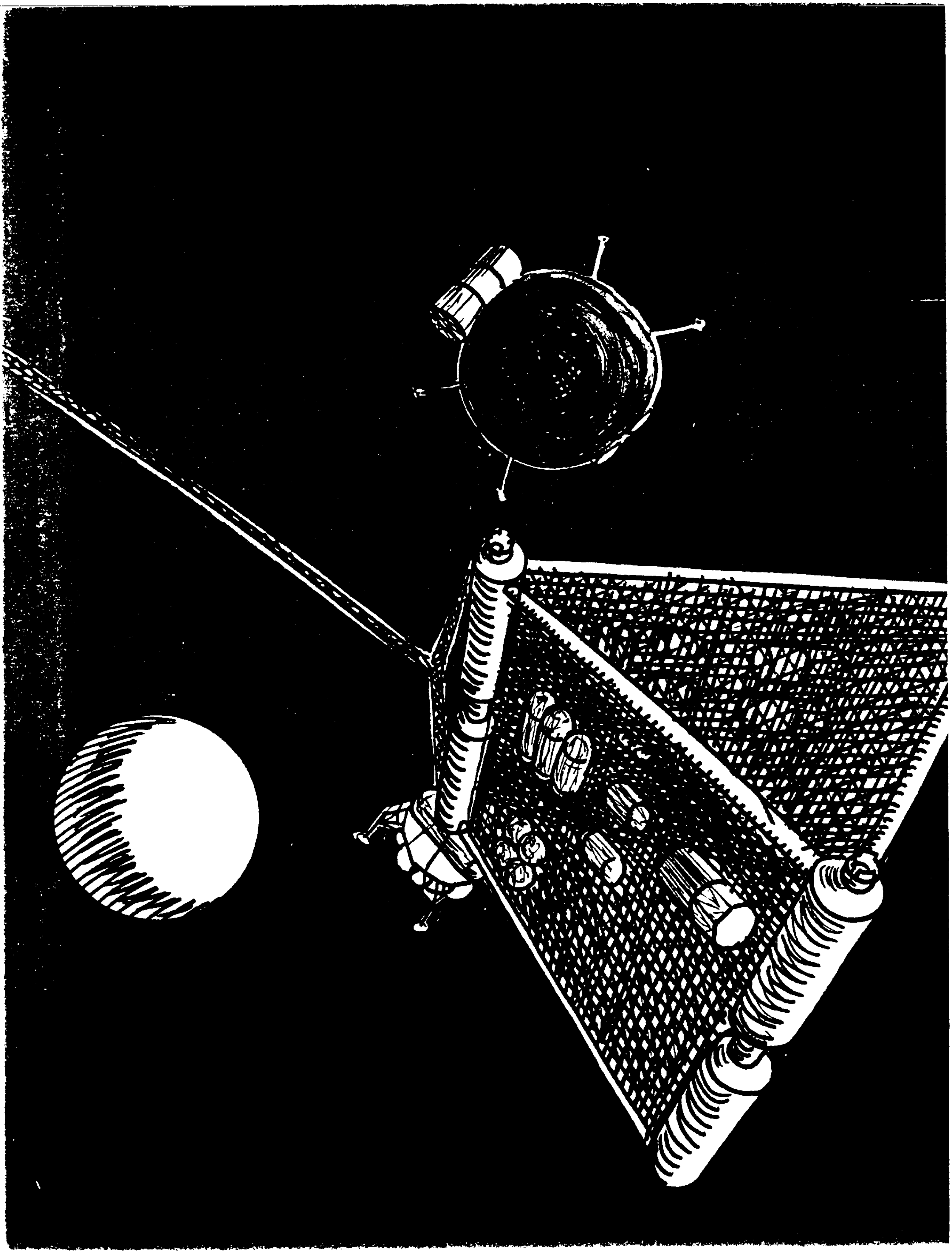

RAWLINGS 85

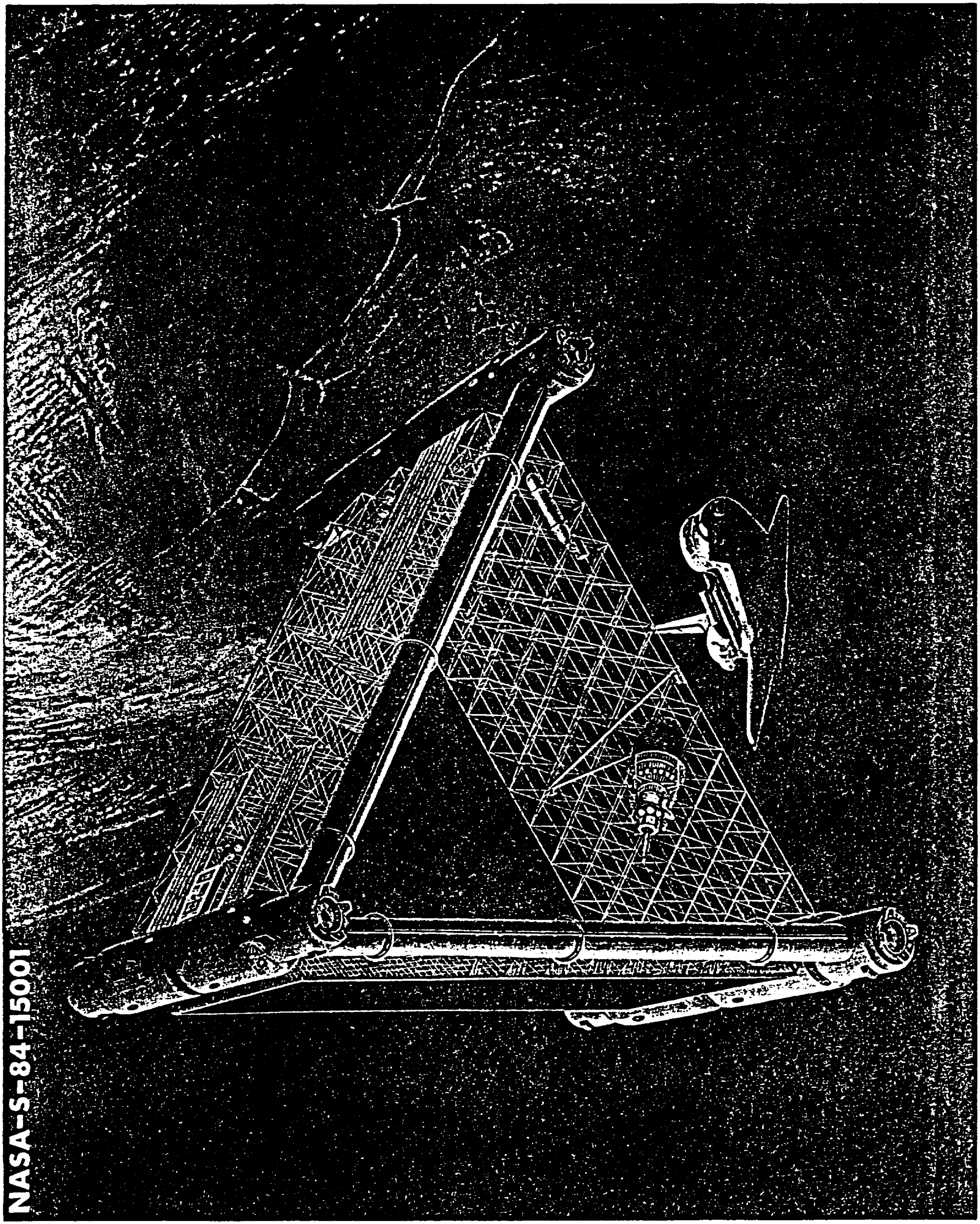
**EARTH-LUNAR L1 SPACEBASE**

**SKETCH NO. 15**

The Earth-Lunar L1 Spacebase is the transportation node for Lunar base operations and the staging area for Mars cargo operations. In addition, the L1 Spacebase provides temporary housing for Lunar Base personnel in transition from Earth-to-Moon or Moon-to-Earth. Due to the location of this spacebase, the structure is in a low-g environment closer to zero-g than an equivalent station at LEO. Due to the nature of this spacebase, the station will not be spun as with the other two spacebases to produce artifical gravity. However, the structural arrangement is adaptable to the additional requirements of servicing hangers, propellant tanks, and vehicle operations (as shown in the illustration). Hence, the commonality of the spacebase design allows for one concept to supply the different needs. The nuclear reactor power system at the end of a 420 foot boom provides .3 MW electric power and 6 MW thermal. Once again, the waste heat can be used to supplement heat energy requirements of industrial facilities on the spacebase. The boom is a combination of an astromast and a tether that provides structural stability and allows the system to be pulled in toward the apex as needed. The delta truss is 200 feet along each arm from the axis of spin to the hab/lab modules. Those modules are separated by 120 feet of truss. Tunnels made of rigidized Kevlar connect all modules. The modules along the bottom apex include a docking port and an industrial facility.

The Earth-Lunar L1 Spacebase can be assembled in LEO or L1 vicinity. The truss can be brought up as one piece that unfolds into the delta shape at which point the additional modules and equipment can be added. The station can accommodate eight people for up to one year duration with additional room for eight transient personnel.

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## MARS PHOBOS SPACEBASE

### SKETCH NO. 16

The Mars Phobos Spacebase is the transportation node for Mars surface activities and the Phobos propellant plant. The concept illustrated here shows a transfer vehicle from the Earth-Mars Periodic Spacebase arriving to bring a fresh crew to the Mars operations theater. This spacebase will also be spinning to provide an artificial gravity environment to the crew and uses the same style of structure as the Earth-Mars Periodic Spacebase. By rotating about the apex of the delta at 2 rpm (minimizing coriolis effects) the habitation and laboratory modules at the other ends experience approximately one-third of a g. The nuclear reactor power system at the end of a 420 foot boom provides .3 MW electric power and 6 MW thermal. The thermal heat in this case can be radiated into space as waste or used to assist in processing of Phobos material for resource utilization. The boom is a combination of an astromast and a tether that provides structural stability and allows the system to be pulled in toward the apex as needed for rotational control. The reactor system and its heat radiators experience about one g. The delta truss is 200 feet along each arm from the axis of spin to the hab/lab modules. Those modules are separated by 120 feet of truss. Tunnels made of rigidized Kevlar connect all modules. The modules along the spin axis include a de-spun docking port and a zero-g laboratory area.

The Mars Phobos Spacebase will be assembled in Earth vicinity (LEO or L1) and propelled into Martian orbit by a cargo orbital transfer vehicle. The truss can be brought up as one piece that unfolds into the delta shape at which point the additional modules and equipment can be added. The station is designed to accommodate up to eight people for two years with the capacity of housing eight additional crew for short transitions.

REFERENCE

5.4 . Hill, P. R., and Schnitzer, E., "Rotating Manned Space Stations," Astronautics, Sept. 1962, 14-18.

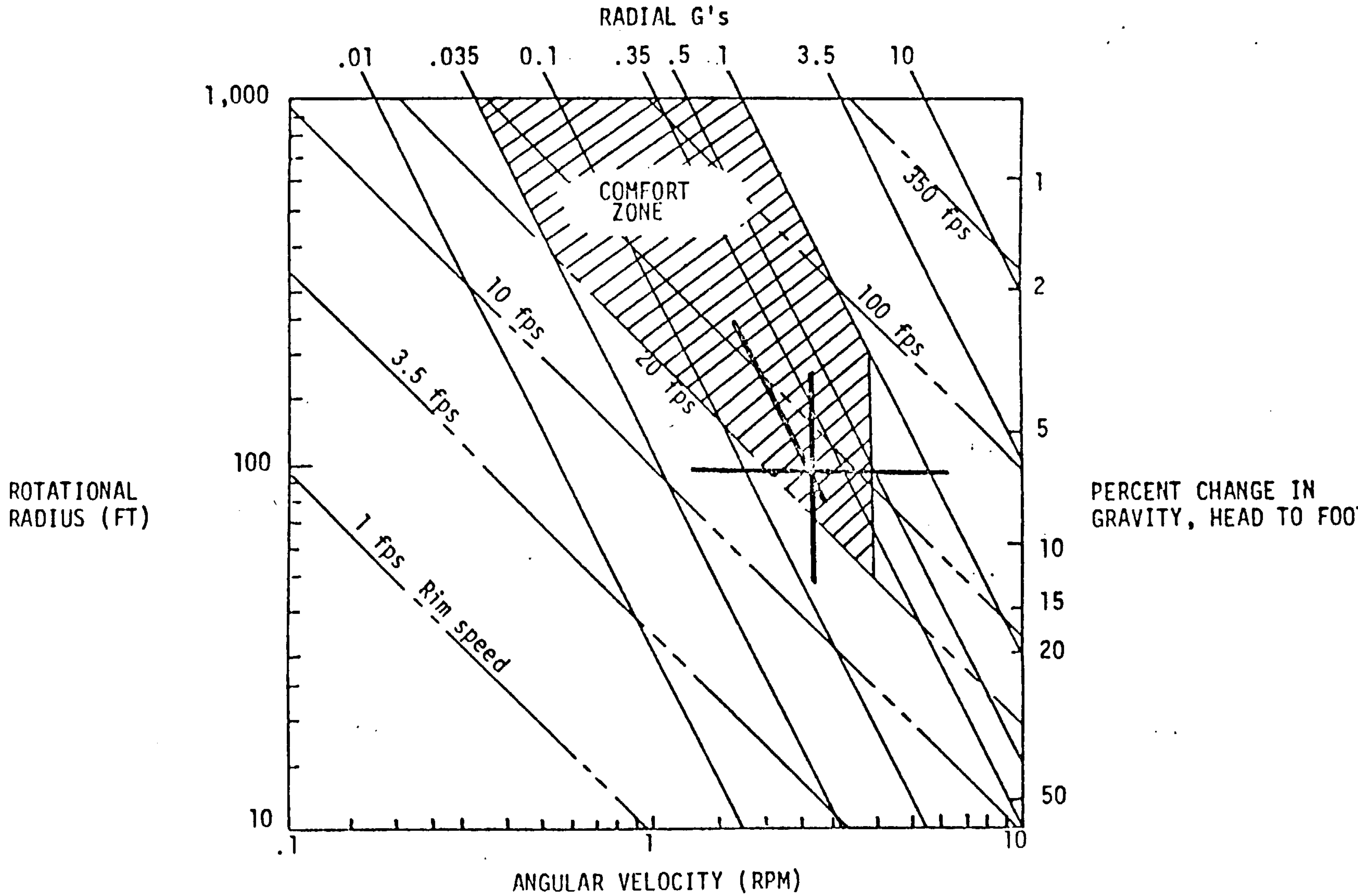
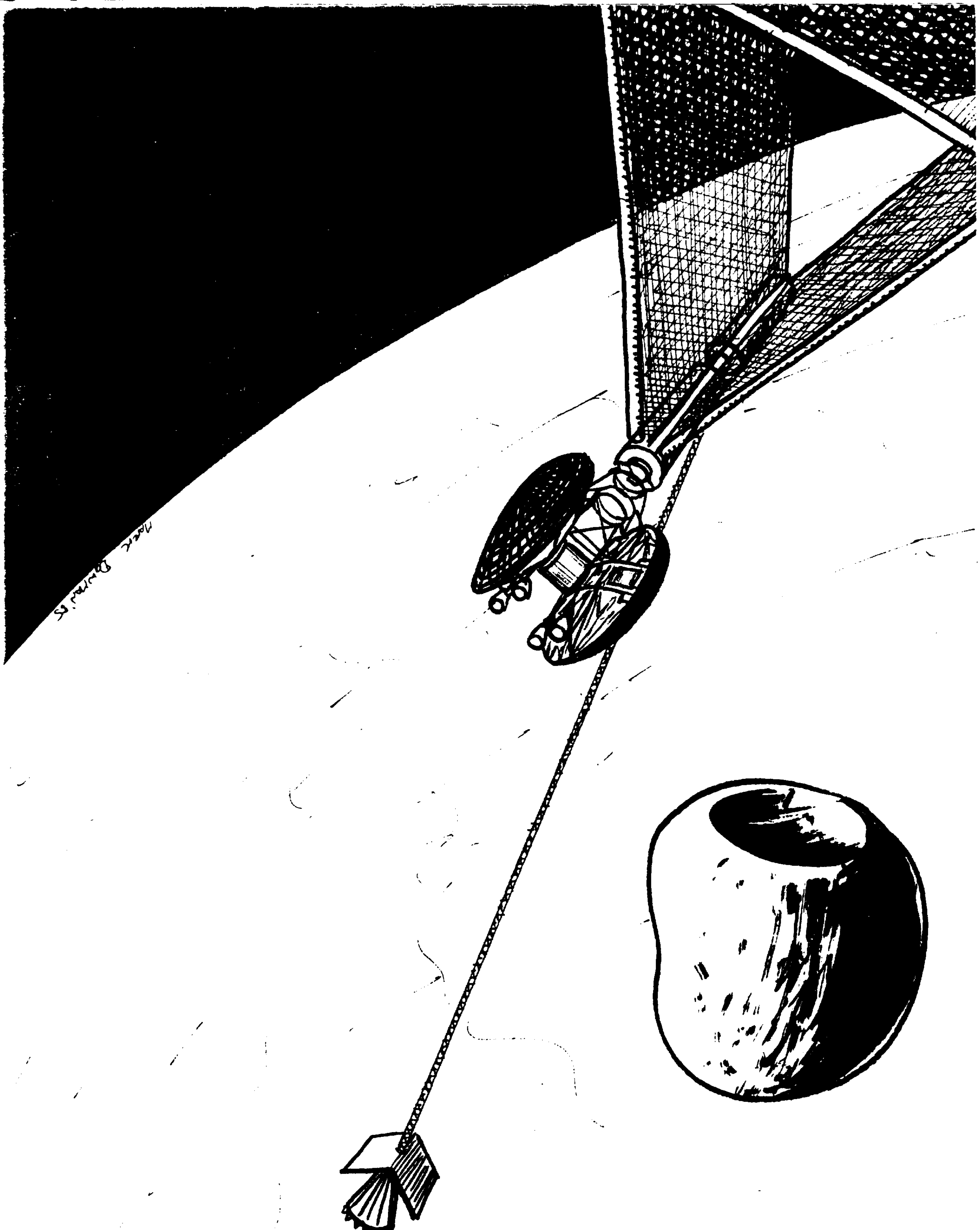



FIGURE 5.6 ROTATIONAL PARAMETERS AND COMFORT ZONE

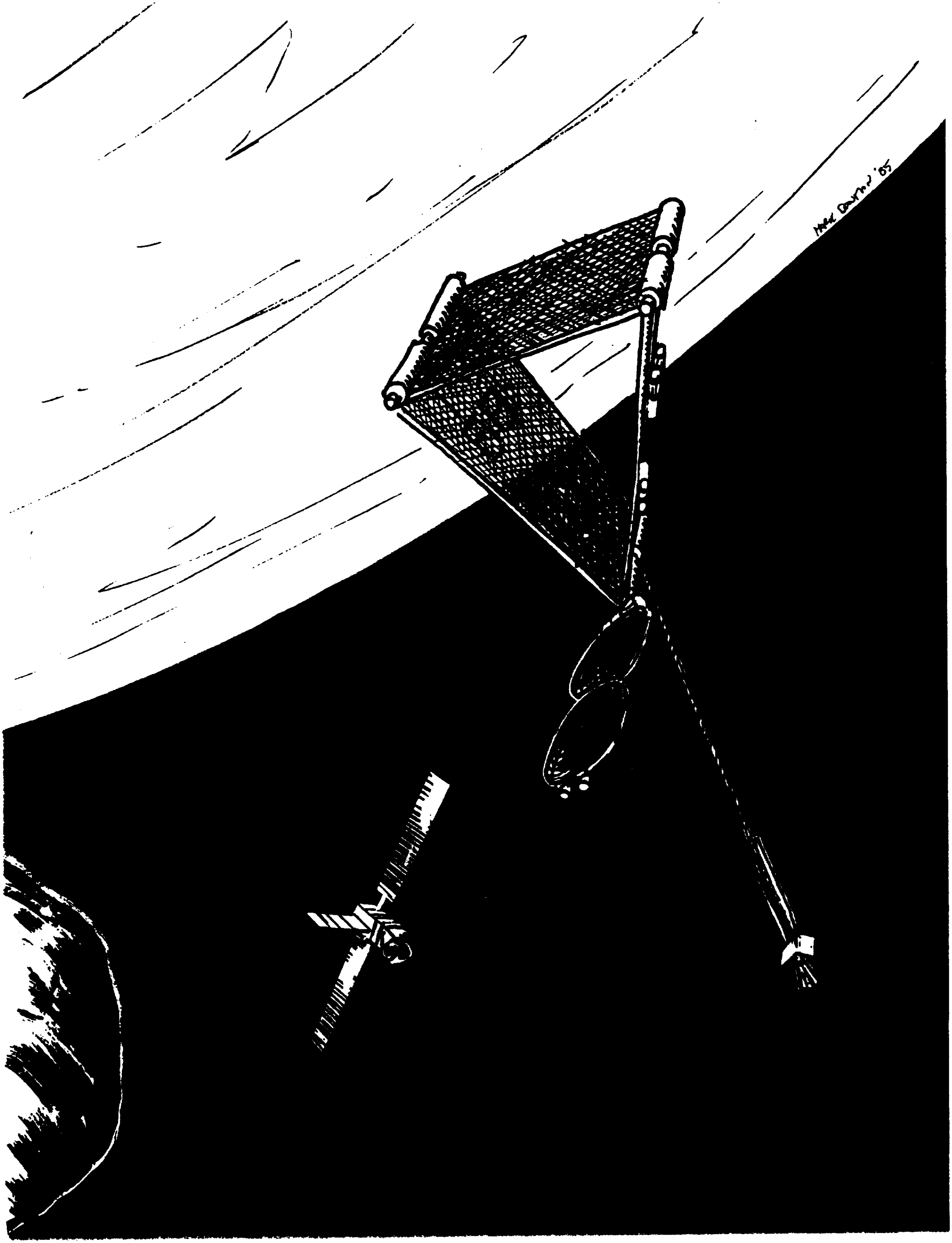


**EARTH-MARS PERIODIC SPACEBASE**

**SKETCH NO. 17**

The Earth-Mars Periodic Spacebase provides the means of efficiently transferring crew from Earth vicinity to the Mars Phobos Station and the Martian Base. This spacebase will be spinning to provide an artificial gravity environment to the crew. In the concept illustrated here, a delta truss makes an Earth pass-by while an Earth-to-Station transfer vehicle is engaged in proximity operations. The delta truss arrangement provides the needed structural integrity to allow the station to spin. Rotating the spacebase about the apex of the delta at 2 rpm provides the habitation and laboratory modules at the other ends of the delta with approximately one third of a g. The nuclear reactor power system at the end of a 420 foot boom provides .3 MW electric power and 6 MW thermal. The boom is a combination of an astromast and a tether that provides structural stability and allows the system to be pulled in toward the apex as needed for rotational control. The reactor system and its heat radiators experience about one g. The delta truss is 200 feet along each arm from the axis of spin to the hab/lab modules. Those modules are separated by 120 feet of truss. Tunnels made of rigidized Kevlar connect all modules. The modules along the spin axis include a de-spun docking port and a zero-g laboratory.

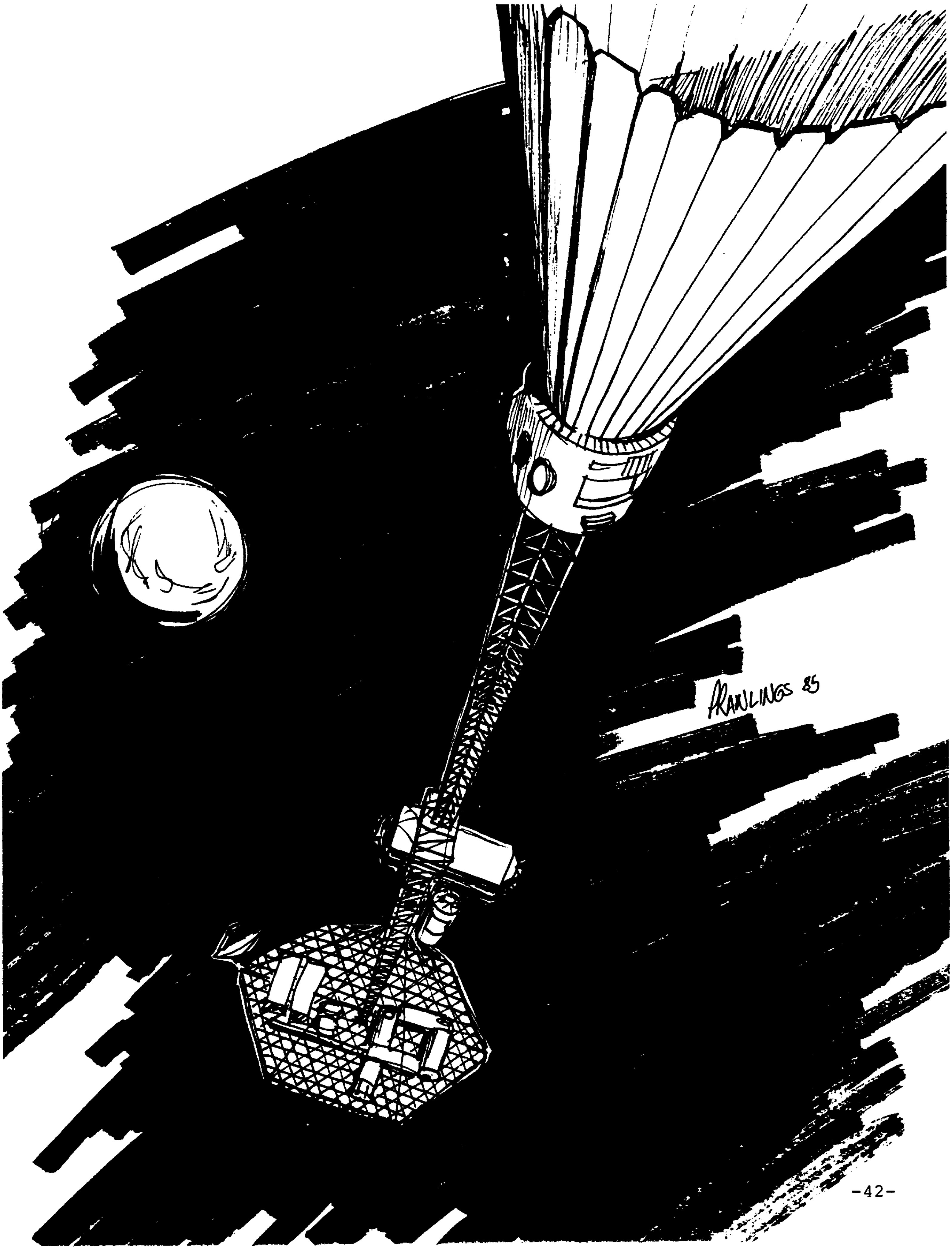
The Earth-Mars Space Base will be assembled in Earth vicinity (Leo or L1) and propelled into its proper heliocentric orbit by a cargo orbital transfer stage. The truss can be brought up as one piece that unfolds into the delta shape at which point the additional modules and equipment can be added. The station is designed to transfer eight people for up to nine months transfer time and can be left in a unmanned dormant state for up to three years. A co-orbiting facility for scientific experiments in route is also included.



## EARTH-MARS PERIODIC SPACEBASE ALTERNATIVE

### SKETCH NO. 18

An alternative Earth-Mars Periodic Spacebase can be constructed by using another proposed IOC Space Station concept. In this illustration, a planar tetrahedral truss is envisioned. At one end, the planar truss is located with habitation, laboratory, and storage facilities. From the center of the planar truss, a box truss runs 200 feet coming to a de-spun docking module. The box truss continues to the nuclear reactor system at the other end. The length of the docking module to reactor truss will be determined by the mass requirements on the planar truss arrangement. The concept will be spun about the docking module at 2 rpm, hence providing the hab/lab modules with one-third of a gravity. The value of 2 rpm was chosen to minimize the crew's problems with coriolis. The nuclear reactor power system provides .3MW electric power and 6 MW thermal. The planar truss is roughly 200 feet along a side and can be deployed in a single shuttle launch. The modules are arranged to provide more than one access per module. The Earth-Mars Spacebase will be assembled in Earth vicinity (Leo or L1) and propelled into its proper heliocentric orbit by a cargo orbital transfer stage. The station is designed to transfer eight people for up to nine months transfer time and can be left in a unmanned dormant state for up to three years.


RAWLINGS 85

## NUCLEAR ELECTRIC PROPULSION FREIGHTER

## SKETCH NO. 19

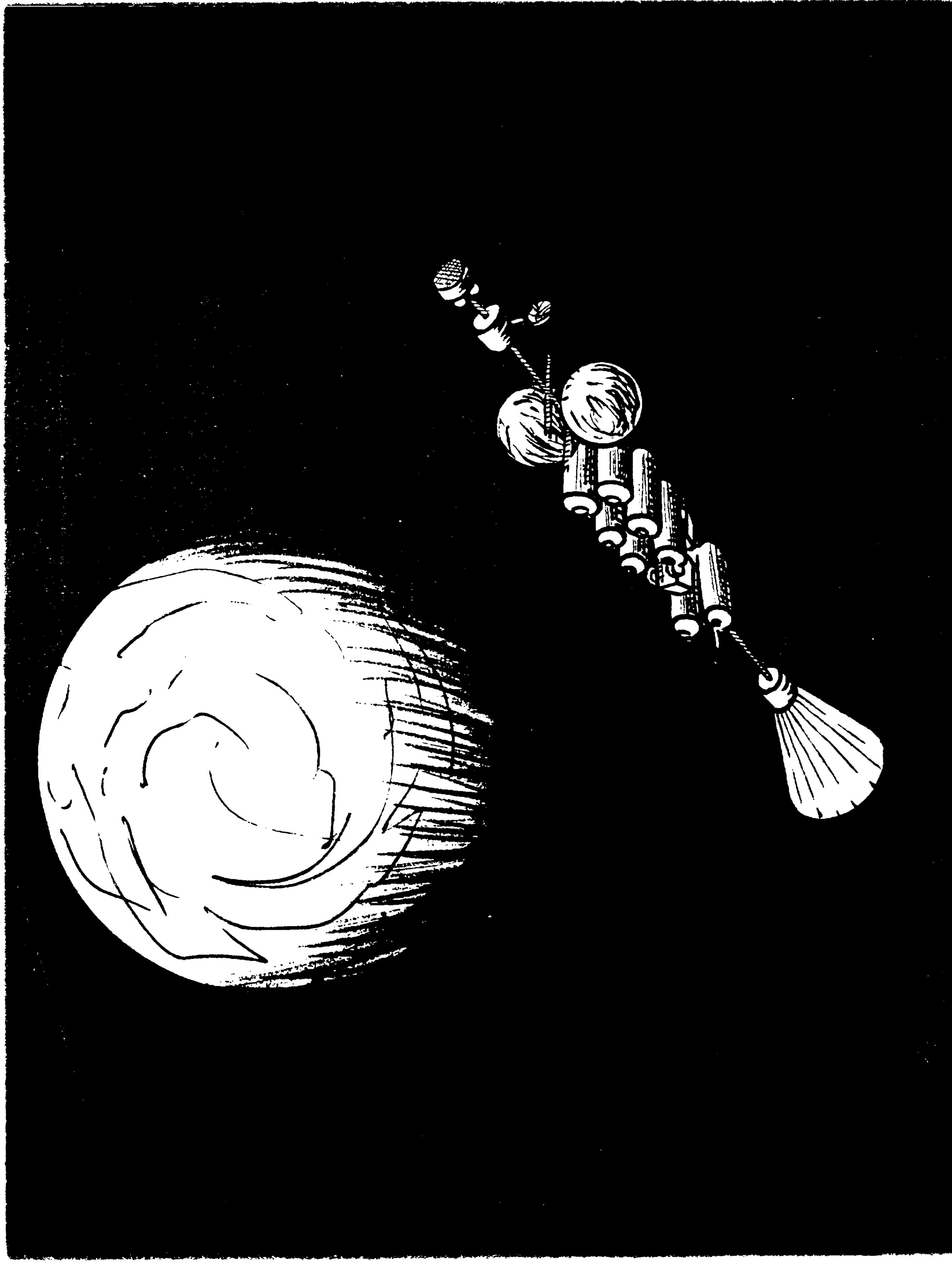
Sketch No. 19 illustrates a Nuclear Electric Propulsion Freighter utilizing mercury ion thrusters. This vehicle is designed to carry about 180 metric tons from Low Earth Orbit (LEO) to the L1 libration point. It uses approximately 100 thrusters powered by a 5 megawatt electric nuclear reactor. The reactor system, including its radiator and man rated sheilding has a total mass of approximately 20 tons and is located on a 25 meter boom at the front of the freighter. The thrusters have a mass of 3 tons and produce 102 newtons (23 pounds) of thrust. The liquid mercury propellant required for the trip from LEO to L1 has a total mass of 29 tons. By using additional propellant and reducing the payload capacity, this vehicle can also be used to take cargo on to Mars.

The outstanding feature of this vehicle is the nuclear power plant. The figure shows a cone-like radiator which operates at a temperature of $900^{o}$ kelvin. It is 30 meters long with a diameter of 30 meters at the large end and 10 meters at the small end. At this size the radiator provides about 2,000 square meters for rejecting the 50 megawatts of thermal energy required to produce 5 megawatts of electric power. The 10 meter cylinder directly behind the radiator contains the reactor, the power converter, and the sheilding. Behind this is the 25 meter boom which is a truss-like structure that is extended to serve as the main structure of the freighter.

The payload support section begins at the end of the reactor boom and extends for approximately 40 meters. Transverse booms extend about ten meters on each side of main structure and are spaced about 5 meters apart. These booms serve as attachment fittings for individual payloads. In this case, the figure shows several base modules, a Long Range Mars Traverse Vehicle, and spare liquid hydrogen tanks.

The avionics module, shown as a 6 meter diameter cylinder about 5 meters long, begins 10 meters aft of the payload support section. This module contains the communication and control facilities for the spacecraft. The thruster and power processing module is mounted 10 meters behind the avionics module. Gimbals are provided between the two to allow control of the thrust direction. The thrusters are mounted in a 3 meter long cylinder about 6 meters in diameter. Although 100 thrusters will not require this much space, spares are added to provide thruster redundancy. The small spheres forward of the thrusters are for propellants. The propellants for the trip from LEO to L1 will only require one of these 2 meter spheres since liquid mercury is very dense. The additional tanks are shown to illustrate that additional propellant can be easily added for extended missions.

Overall, the freighter is 133 meters long and has a mass of about 234 tons in Low Earth Orbit.



## INITIAL MARS BASE

## SKETCH NO. 20a

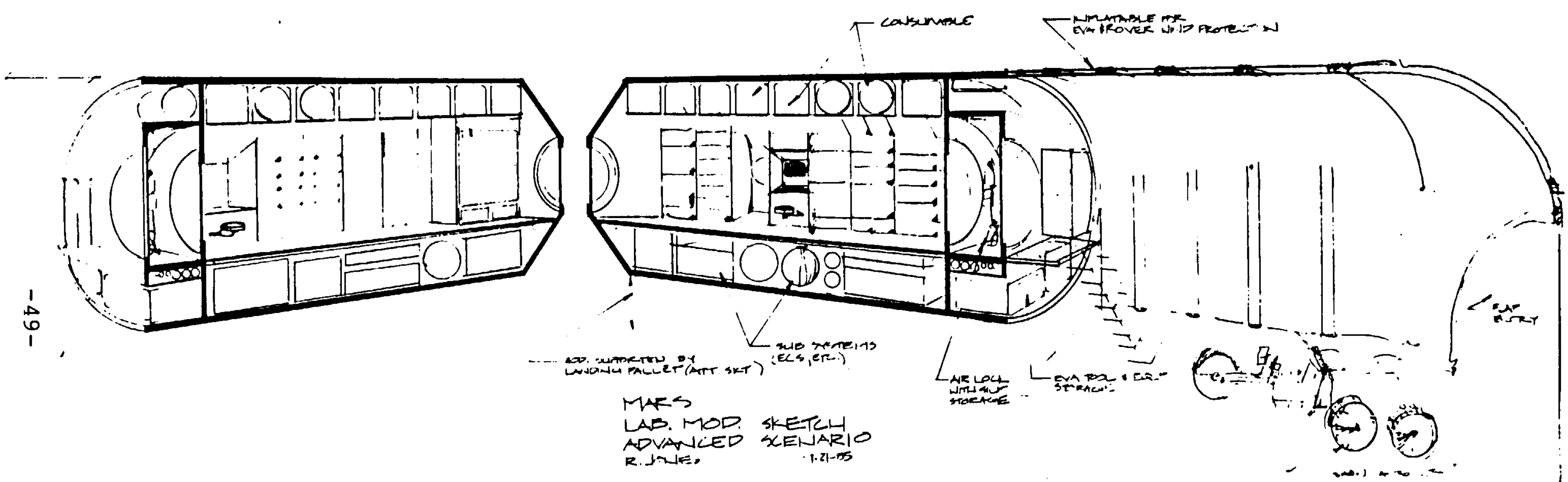
This artist's illustration shows the elements that might be required for a first mission base site configuration. The T configuration shown includes habitat, laboratory, and EVA modules simular in size and design to Space Station modules. The inflatable structure in front of the T is a maintenance garage/$CO_2$ washdown area proposed to eliminate the problems of dust and possible superoxide contaminants on suits and other equipment. Also, in the foreground is a lunar rover type vehicle and two crewmembers in a self-contained tracked transporter heading toward the ascent vehicle (left background). A prototype Martian ISPP (In-Situ Propellant Production) plant is set up in the right backgrond along with an SP-100 nuclear power plant.


NASA

**PRELIMINARY MARS HABITAT INTERIOR**

**SKETCH NO. 20b**

This artist's illustration shows the interior of a habitation module containing all the required facilities for human existence on the Martian surface.

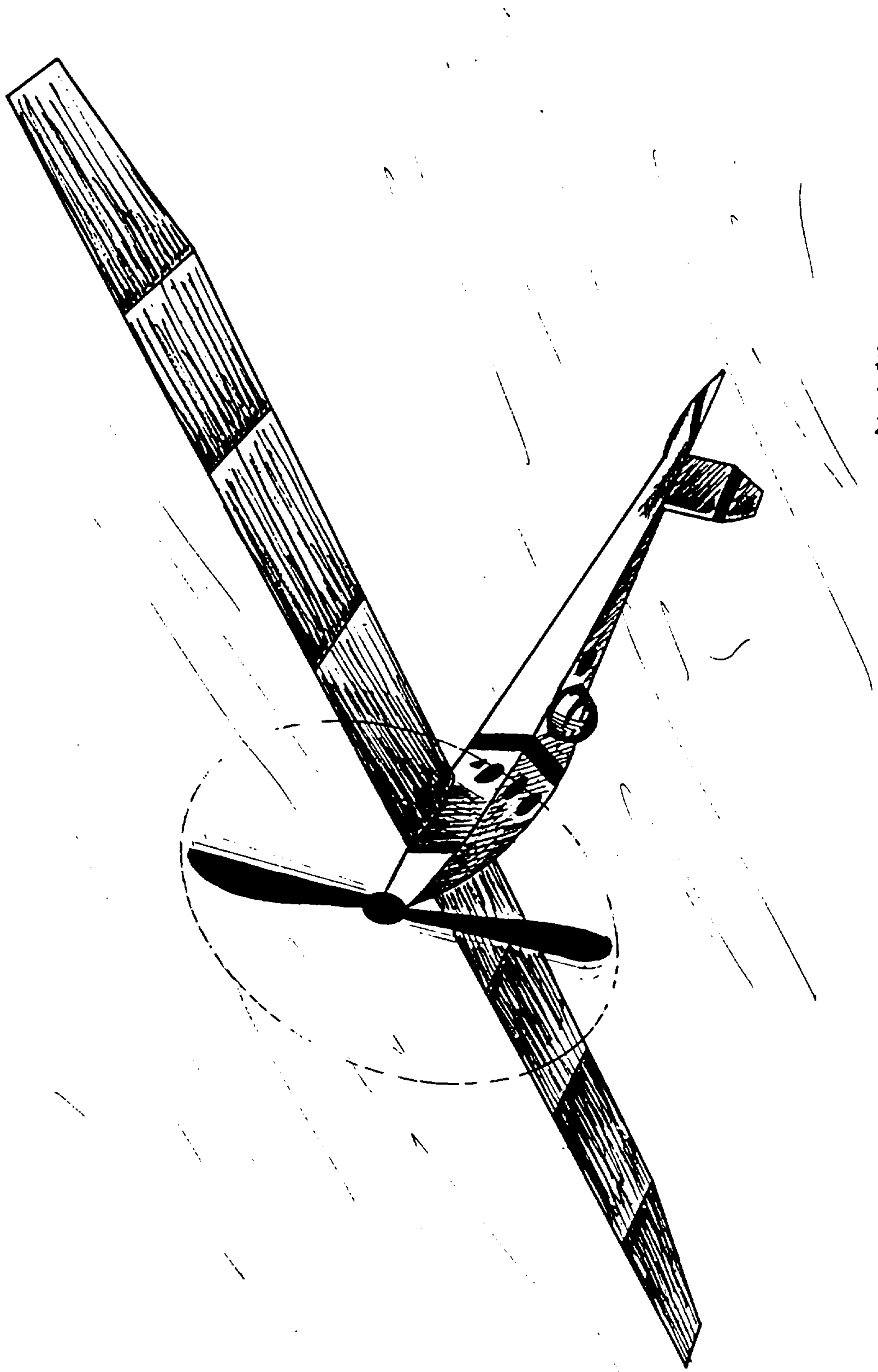



| PART NUMBER | DESCRIPTION | MATERIAL | SPECIFICATION |
|---|---|---|---|
| DIMENSIONAL TOLERANCE UNLESS NOTED OTHERWISE .X ± .1 .XX ± .01 .XXX ± .010 ANGULAR ± | SIGNATURES / DATE: DR, ENG, CH, APP, AUTH | NATIONAL AERONAUTICS & SPACE ADMINISTRATION LYNDON B. JOHNSON SPACE CENTER HOUSTON, TEXAS | |
| SURFACE FINISH IN MICROINCHES RMS UNLESS NOTED OTHERWISE ✓ | | CODE IDENT NO. / SIZE D / DWG NO. | |
| NEXT ASSEMBLY | | SCALE | SHEET |

**MARS AIRPLANE**

**SKETCH NO. 21**

This illustration depicts a Mars airplane concept designed by JPL. As a scientific platform, it provides an excellent means of obtaining data in a resolution range intermediate to surface vehicles and orbiters. It has great versatility to perform a variety of missions: conduct aerial surveys, land instrument packages, collect samples, and perform atmospheric sounding. The Mars Airplane has many characteristics of a competition glider on Earth. Two versions of the plane, a cruiser, and one with soft landing and takeoff capability, have been designed. Maximum range and endurance are 10,000 km and 31.1 hours with a 40-kg payload.

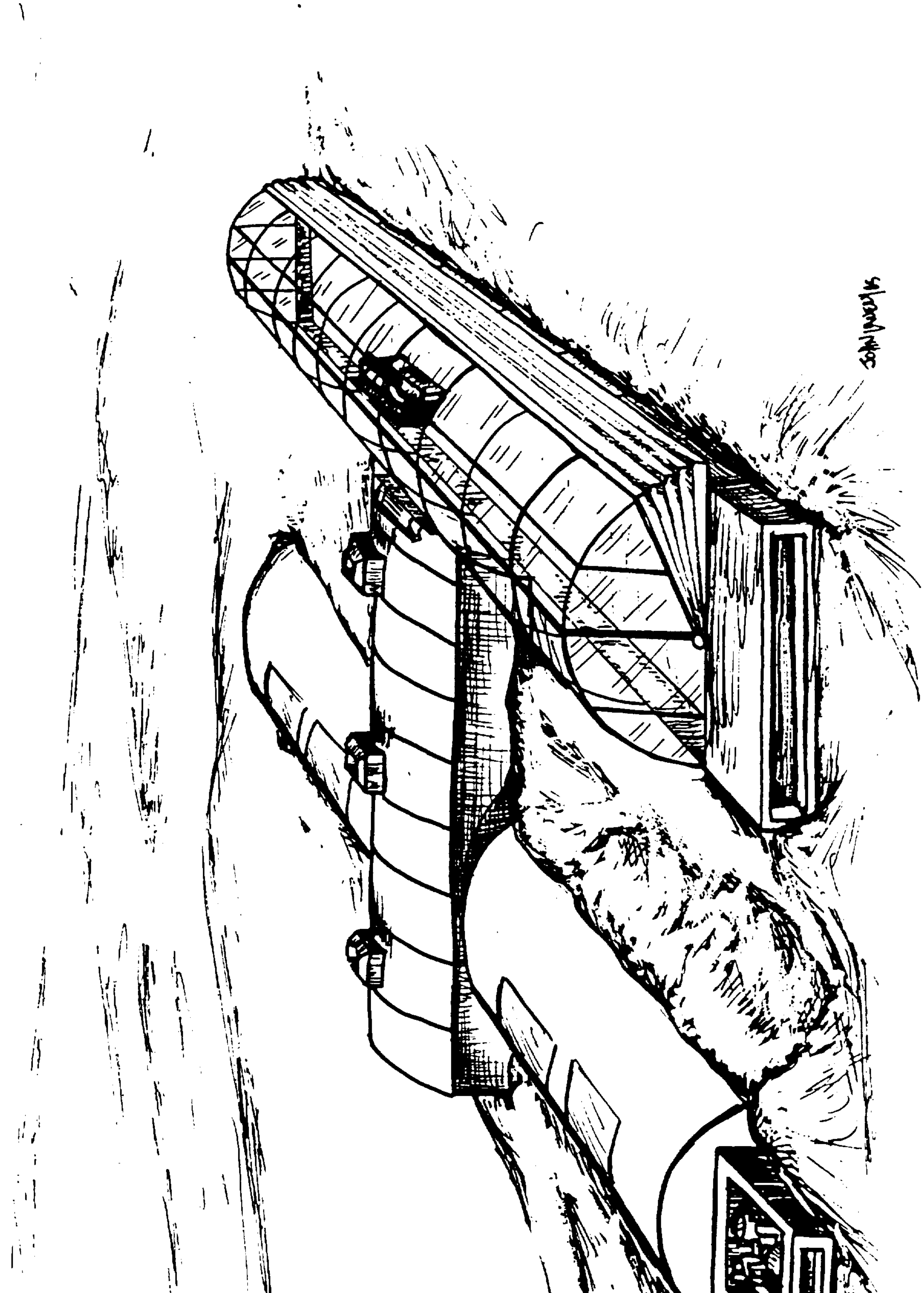


## MARS GREENHOUSE

## SKETCH NO. 22

Sketch No. 22 illustrates a concept for a growth configuration food production facility. The shelter on the left is an inflatable structure used to produce low growing plants, fungi and algae. Artificial lighting would be required to enhance the small amount of light admitted through the transparent patches of material. The structure on the right is erectable, made from some light-transmitting material (glass, fiberglass). Many levels of higher-growing plants and vegetables would be produced in this structure. On the end of each structure is machinery such as pumps, feeders, recyclers, and heaters, necessary to automate the processes. In addition, there would be space in the erectable structures attached to the hard-shelled greenhouse to store harvested food and to process it for long shelf life. There is a long semi-erectable structure connecting the two greenhouses allowing them to share airflow and temperature controls. On the top of this connection are located devices to regulate humidity and possibly process potable $H_2O$. At the end of this connection would exist a hatch compatible to that of the habitat modules for eventual linking of the two environmental control systems.

For solar event protection at least one greenhouse, the erectable one, can be shielded somewhat by attaching a shade which can be pulled up and over the glass planes. This is shown partially deployed in the sketch.

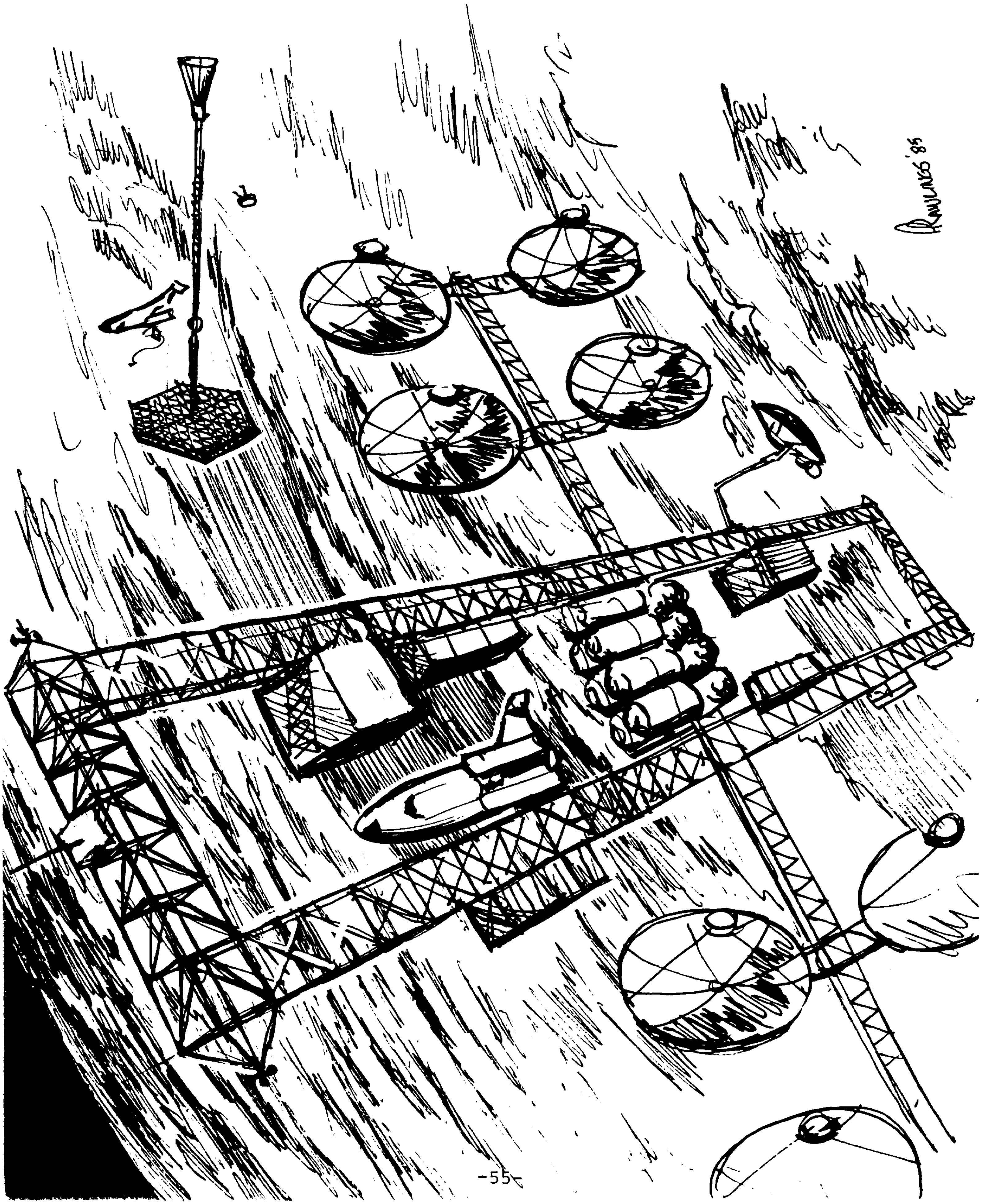


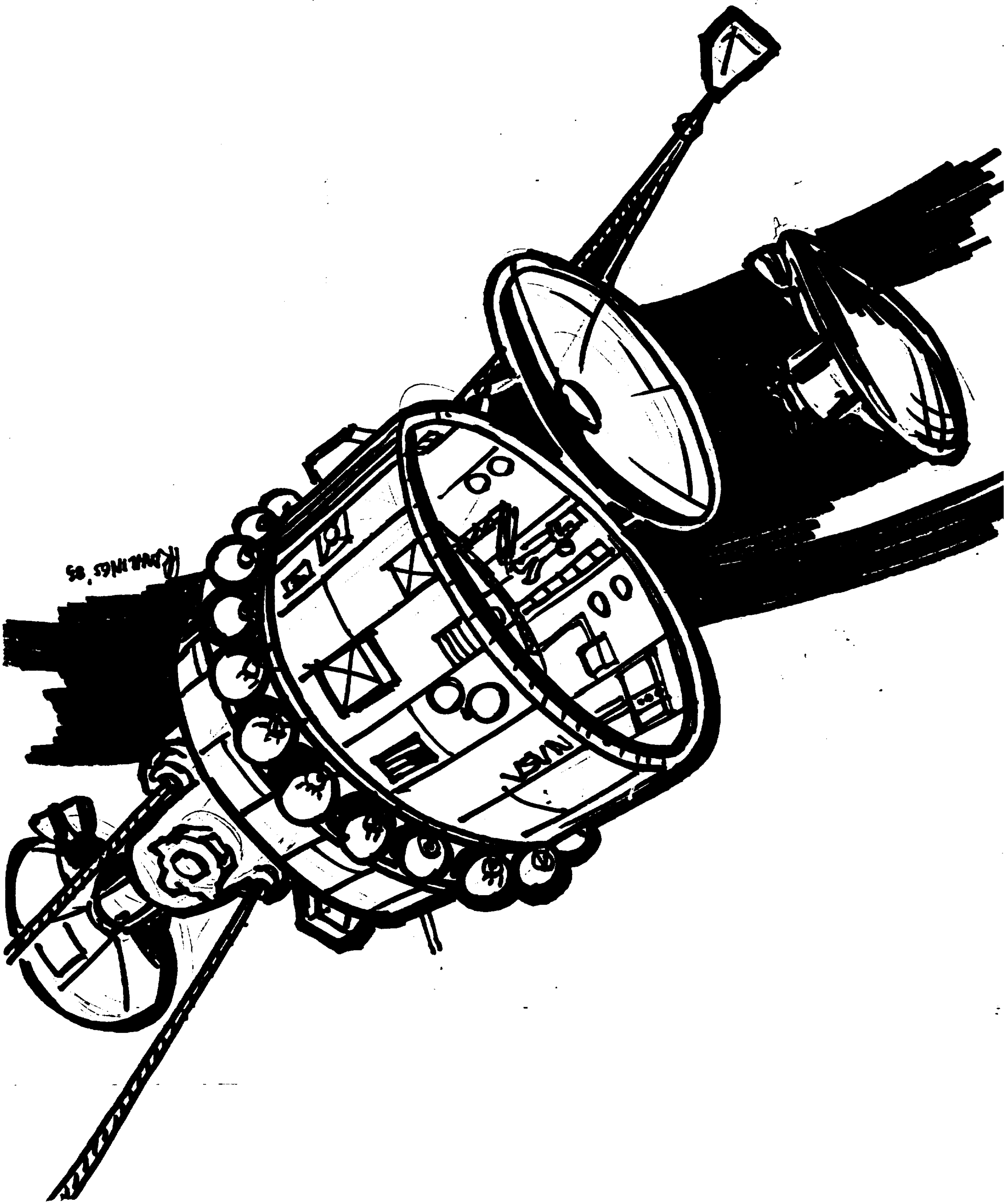
## OPERATIONS IN LEO

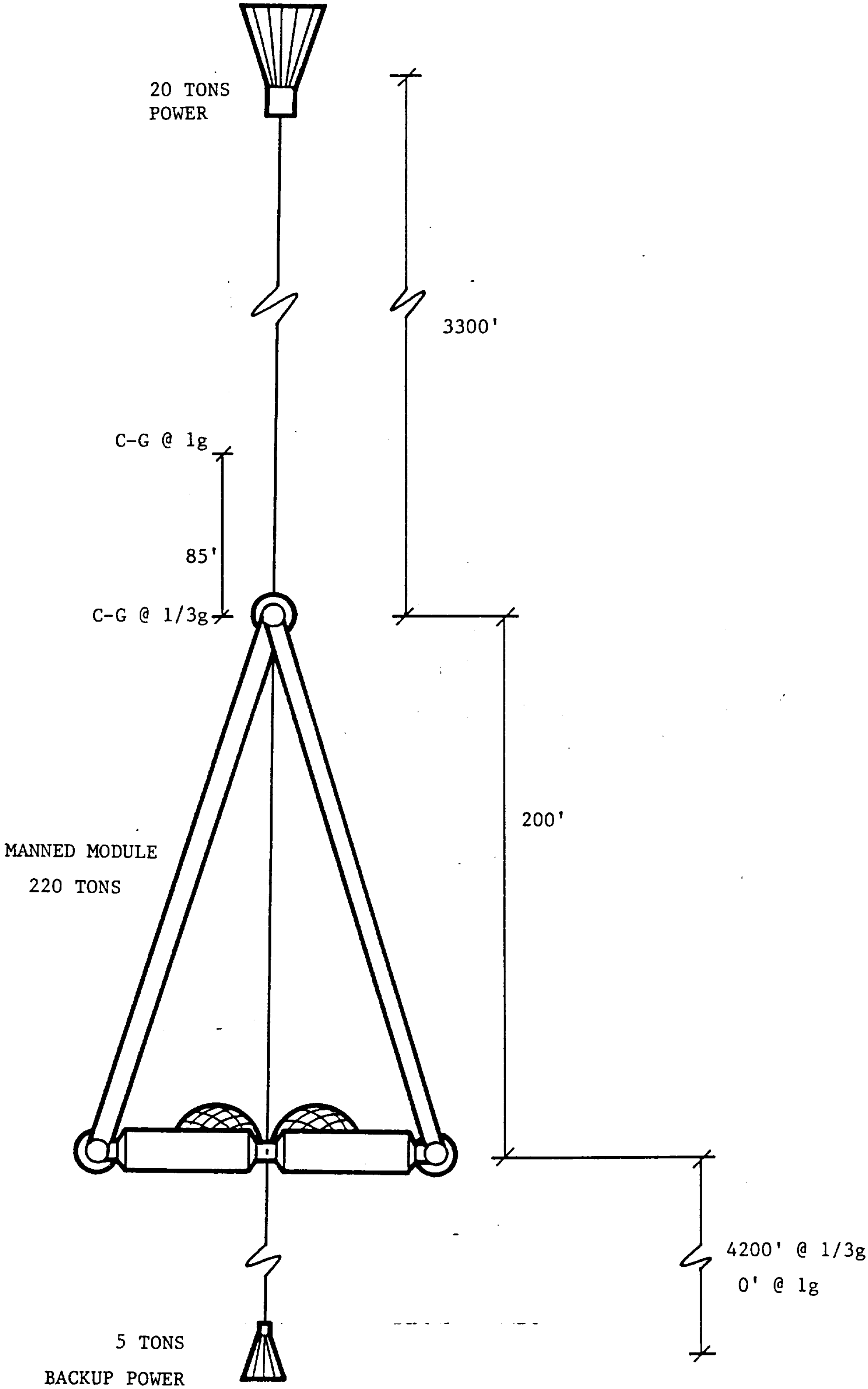
## SKETCH NO. 23

This sketch shows the growth configuration Space Station in low Earth orbit with a second generation Shuttle approaching it. A periodic Space Station for Earth-Mars transfer is being assembled nearby. The low Earth orbit (LEO) Space Station is the first step in any scenario that involves the construction of large assemblies in space.

In order to utilize the present and later versions of the Shuttle most effectively, there must be a base in low orbit to which spacecraft parts, men, and tools can be delivered. This base will provide the power, habitats, attitude and thermal control, and tools for the assembly of large structures. Spacecraft such as the periodic space station will require long periods of time, and many Shuttle flights to assemble in orbit.






20 TONS
POWER
3300'
C-G @ 1g
85'
C-G @ 1/3g
200'
MANNED MODULE
220 TONS
4200' @ 1/3g
0' @ 1g
5 TONS
BACKUP POWER

## PERIODIC SPACE STATION
## OPERATIONAL TRANSPORTATION SCENARIO

Once the several Periodic Space Station (PSS's) have been installed in their various orbits, normal operations can begin.

Transportation opportunities occur approximately every two years as the planets come into conjunction.

During this period, a PSS on a short Earth-Mars leg passes Earth. The personnel transporter, two OTV's with manned module, leaves Earth on a hyperbolic trajectory designed to match that of the PSS. One OTV acts as a first stage and returns to low Earth orbit via aerobraking after burnout, also emptied and discarded during this injection. The second OTV and manned module rendezvous with and docks to the PSS. Enough propellant is left in the OTV for Mars arrival operation.

The crew debarks from the OTV manned module and enter the PSS. The OTV remains with the PSS during the flight to Mars.

As the PSS passes Mars, the crew re-enters the OTV manned module and debarks. The OTV maneuvers to an aero intercept of Mars and performs an aerobraking entry into an elliptical Mars capture orbit. After the aerobraking pass, the OTV uses its remaining fuel to rendezvous with the martian moon Phobos. Here, personnel transship to a Mars landing vehicle for transport to the surface.

The OTV is fueled, two auxiliary tanks are added and an OTV booster stage attached. It is then ready to transport a crew back to Earth.

When a PSS on the short Mars-Earth leg approaches, the returning crew launches to Phobos in the Mars launch/landing vehicle. There they transfer to the OTV stack just described. At the proper time the OTV boosts to a hyperbolic rendezvous with the passive PSS. The booster stage OTV aerobrakes back to martian orbit after burnout (enough propellant is reserved to return to Phobos). The top OTV plus some propellant and the manned module rendezvous with the PSS for the trip to Earth. During the trip, the crew again resides in the PSS.

At Earth, the crew again enters the OTV and separates to an Earth intercept course. Just before aeroentry, the OTV propulsively shows about 2 km/sec. to bring entry velocity to an acceptable level (down to 35,000 fps).

The OTV then aerobrakes to a low circular orbit and the rendezvous with the Space Station.

For operations to and from L1 the same basic scenario is used except that a Space Station at L1 is the initial and final destination and the final aerobrake maneuver at Earth places the manned OTV in a high ellipse followed by propulsive rendezvous with the L1 station.

**MANNED MARS BASE**

In the attached illustration, a Mars base has been established in an ancient water eroded canyon. Members of the exploration team in the foreground are wearing NASA Ames designed hybrid hard/soft type pressure suits. Donning of these suits is simplified by a large door-like backpack. The traverse vehicle they are using consists of a command module containing guidance, navigation and communication equipment followed by a habitation module and a power module.

On the floor of the canyon, greenhouses provide most of the food for the base. The environmentally controlled enclosures use compressed Martian atmosphere to provide concentrated carbon dioxide for the hybrid plants and vegetables.

The habitat/laboratory modules of the central base are buried beneath a meter of soil for radiation protection. The lightweight crane and trailer near the base habitat modules were used in their construction. They also are used for the moving and assembly of other base components such as greenhouses, SP100's, vehicles, etc. Beyond the central base is the atmosphere processor unit which compresses, then converts the Martian air into a breathable atmosphere and propellant.

A tunneling device on the tracks is preparing a second generation base. The excavated material from the tunneling operation is transported away by small teleoperated hopper cars. Once finished the tunnels are sprayed with a bonding resin and pressurized.

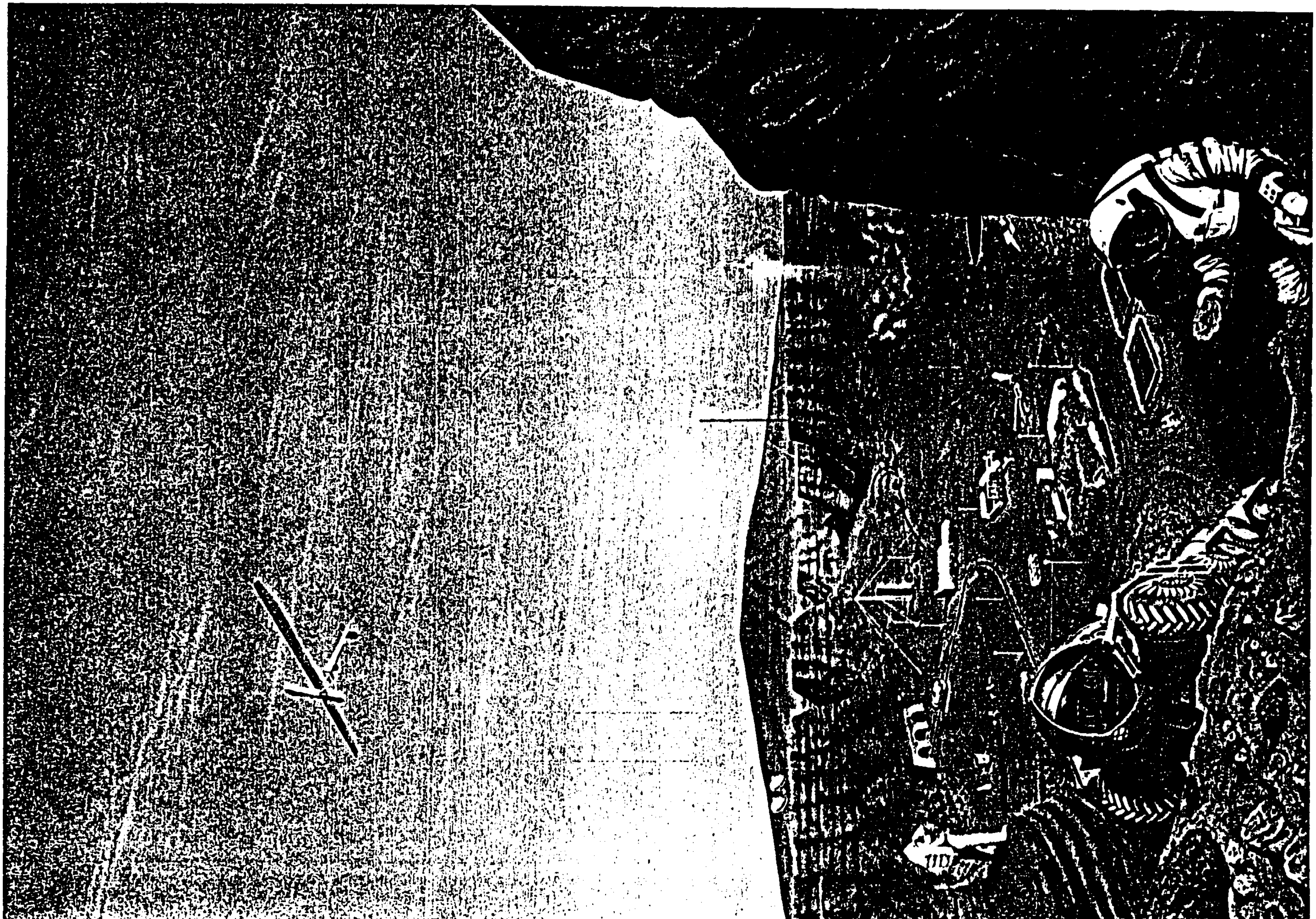
The Mars airplane is used for unmanned exploration and scientific missions.

Power for the base is provided by SP100 derived nuclear power stations.

National Aeronautics and
Space Administration

S- 85- 31477

Lyndon B. Johnson Space Center
Houston, Texas 77058

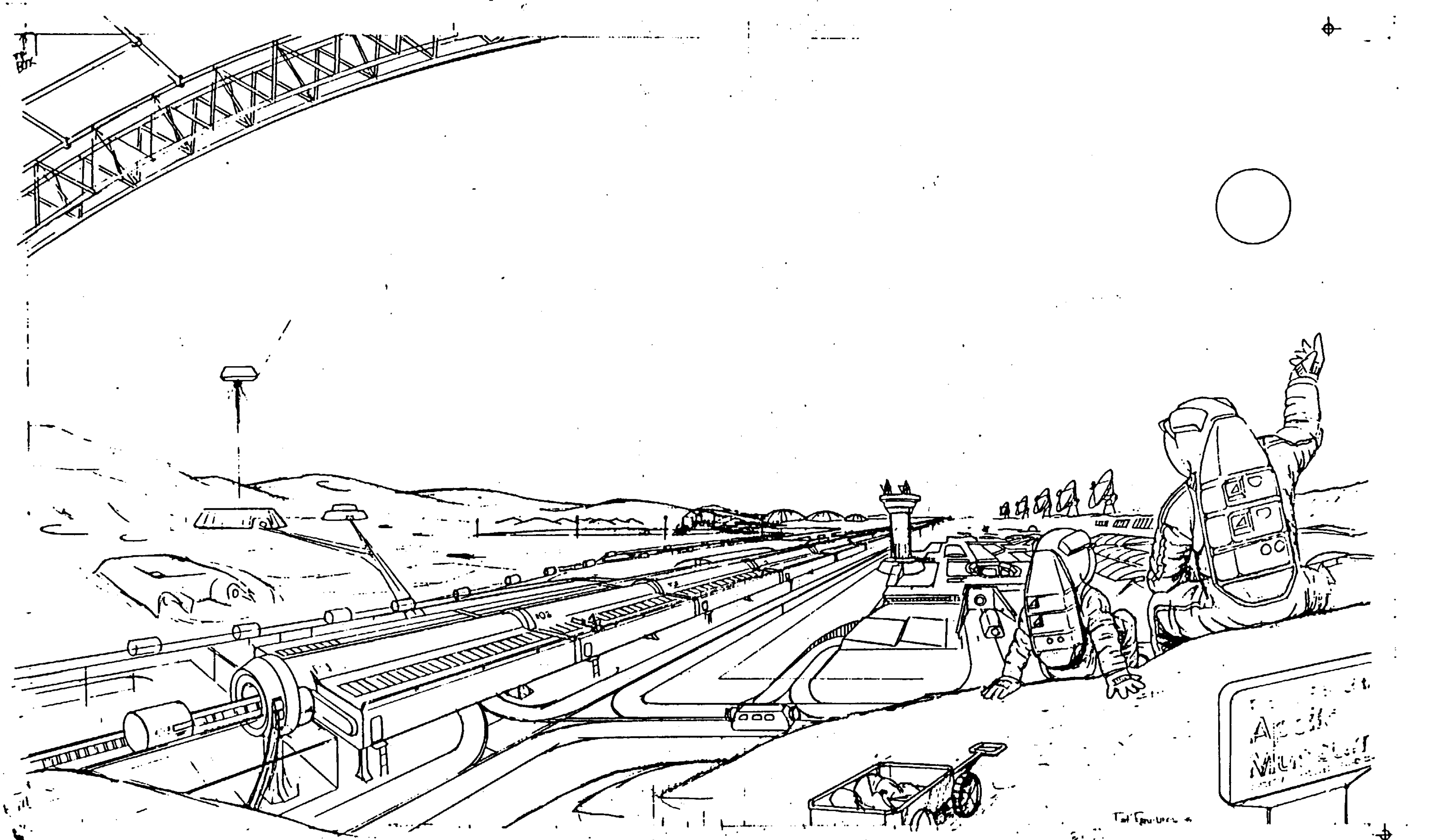


## SECOND-GENERATION LUNAR BASE

The attached illustration depicts the view of a second generation Lunar Base from just within a partially completed Quonset style surface structure. Similar completed structures are in the right background between the two Lunar Base personnel. The pressure suits they are wearing are based on a NASA Ames Research Center modular design.

On the left are the buried habitat modules of the initial Lunar Base. Beyond, a lander is on final approach to one of several landing/launch pads. Landings and launches are coordinated from the control tower at right center. People-mover type conveyors are used for surface transport near the base.

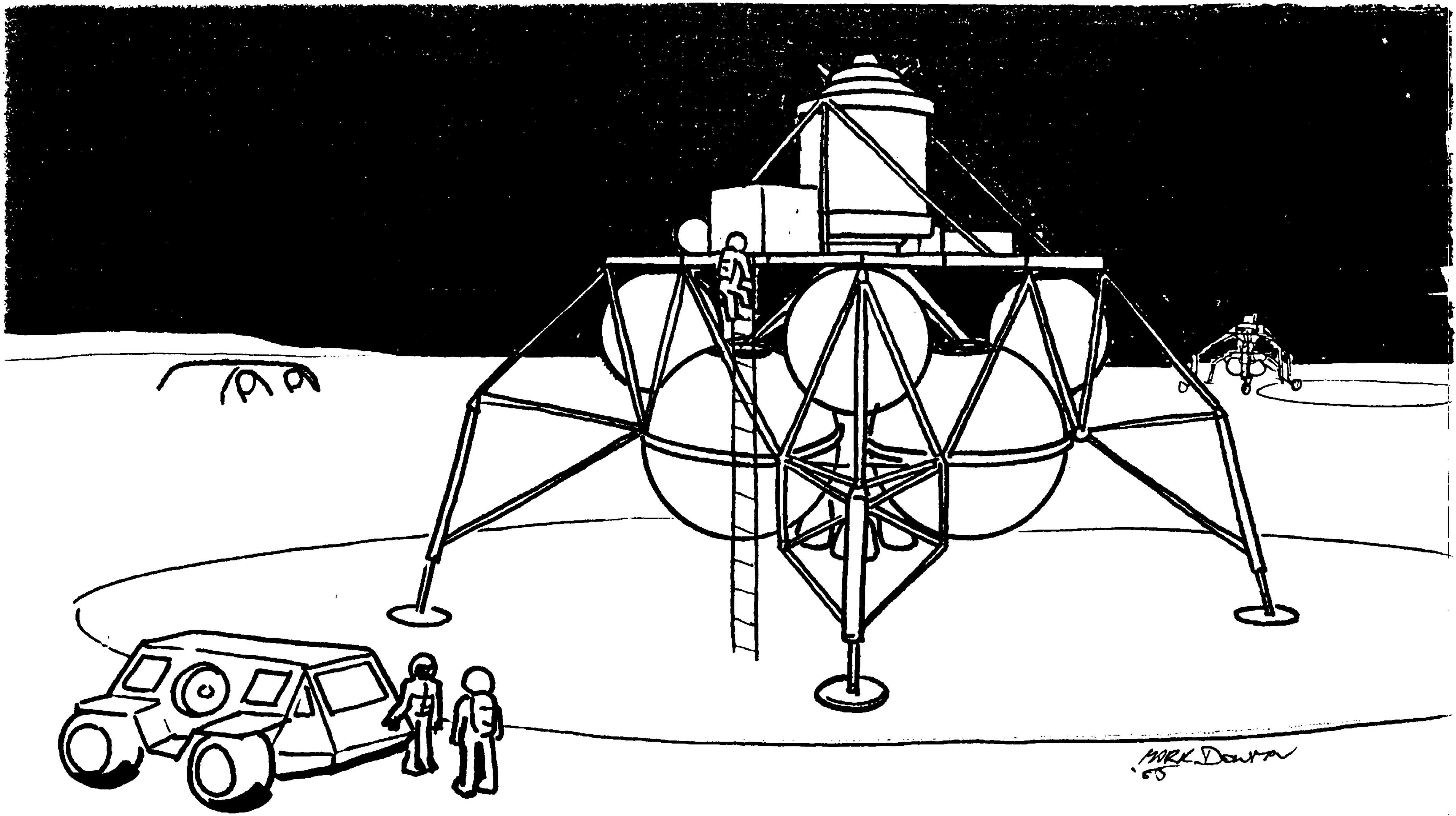
A payload and bucket is just entering the mass-driver which dominates the center. The mass-driver delivers lunar oxygen or surface derived materials to a remote mass catcher in space. A lunar oxygen plant is positioned in the center background. Plant electrical requirements are provided by SP-100 nuclear power sources. Power for the advanced base is supplied by solar collectors constructed from lunar derived materials positioned on a ridge at right.



## PERSONNEL CARRIER TO THE LIBRATION POINT

The Reusable Lunar Launcher/Lander (R-LEM) described in the lunar base study (Impact of Lunar and Planetary Missions on the Space Station) carrying a manned module from the same study is properly sized to shuttle personnel from the lunar surface to either libration point (L1 or L2).

The R-LEM uses $LO_2/LH_2$ propellant, has a burn out weight of 5.2 metric tons and 30 m tons of usable propellant. It has four $H_2$ and four $O_2$ tanks, all spherical. The mixture ratio is 7:1 and the Isp (effective) = 455 sec. There are 5 throttleable engines on the lander of 3 to 4 thousand lb. thrust each. The $H_2$ tanks have a diameter of 3.6 m including .3 m (1 ft.) of insulation all around. The $O_2$ tanks are 2.6 m in diameter including .1 m (3 in.) of insulation all around. The manned module is 5 m long, 2.6 m in diameter, weighs 5 m tons (manned), and can transport 6 to 10 crew.



## VARIABLE-GEE RESEARCH FACILITY ON LEO SPACE STATION

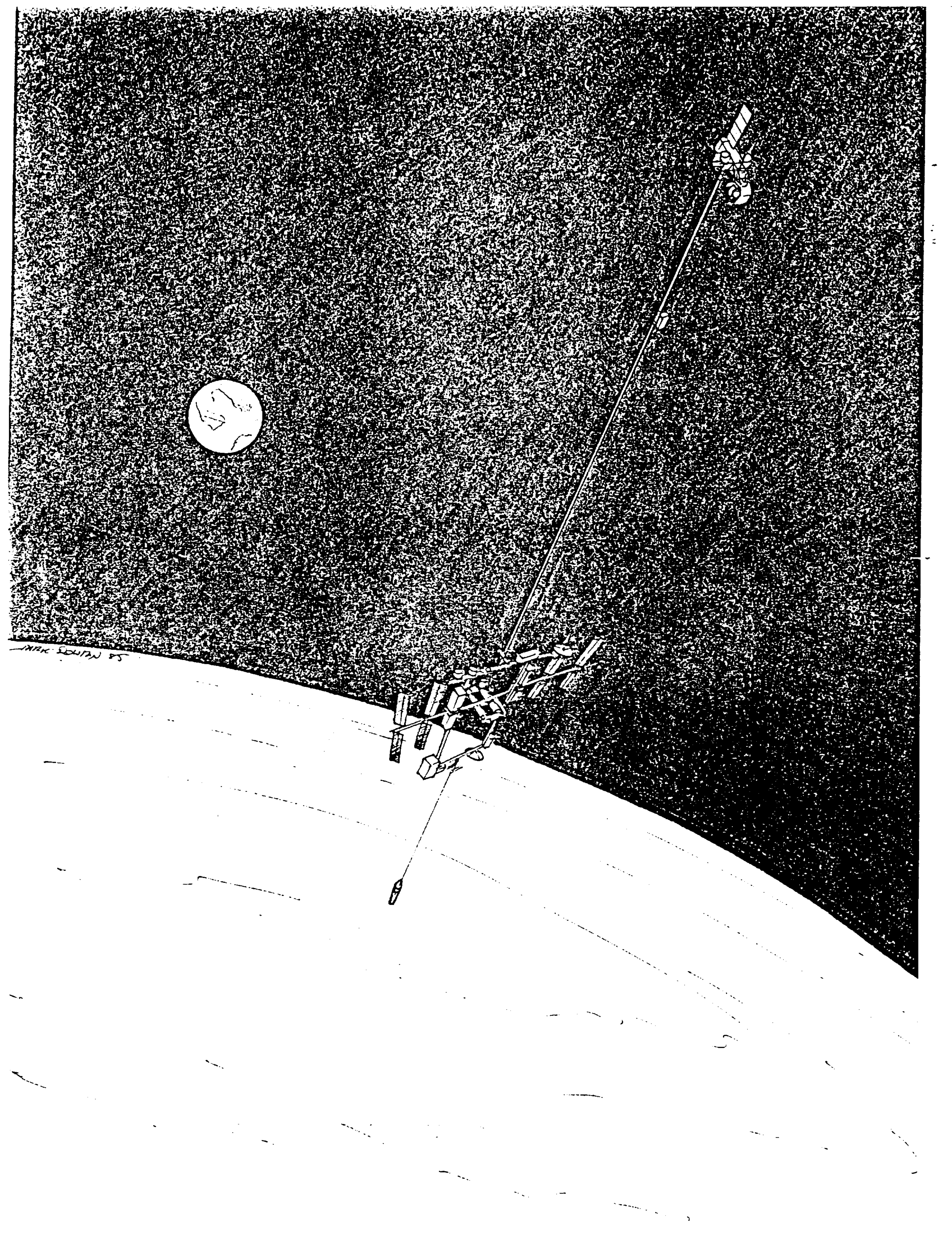
The attached sketch depicts a variable-acceleration research platform tethered to the Dual Keel configuration Space Station. The tethered platform provides a low contaminate/low disturbance environment away from the Space Station for scientific instrumentation and equipment payloads while maintaining the advantage of Space Station proximity and accessibility. Also, because power, data relay, communication and platform control can be transferred through a conducting tether from the space station, the platform manifest is simplified which translates into significant mass and cost reductions.

The science platform's acceleration is varied by changing the length of its tether via a winch device that includes a cable drum, drive and tether alignment assembly. The relationship between tether length and platform acceleration (in LEO) is:

| Length (Km) | Acceleration (Gee) |
|---|---|
| 0.1 | $3.8 \times 10^{-5}$ |
| 0.5 | $1.9 \times 10^{-4}$ |
| 1.0 | $3.8 \times 10^{-4}$ |
| 5.0 | $1.9 \times 10^{-3}$ |
| 100 | $4 \times 10^{-2}$ |

The winch units are located at both the zenith and nadir ends of the space station. The cable-drum drive units will probably be continuously running at a constant speed to reduce Space Station moment changes. Then by engaging the cable-drum, the tether length can be changed. To maintain the microgravity environment of laboratory modules at the Space Station center-of-gravity, a tethered counter-mass is reeled from one end of the Station as the science platform tether length is changed at the other. The Space Station center-of-gravity location could be automatically controlled using feedback from accelerometers at the Space Station and manipulating the counter-mass winch rate.

In the sketch, a remote-controlled crawler with end-effectors is stationed along the tether for servicing missions to the science platform. A Remote Manipulator System grapple is installed on the platform for maintenance purposes. An Orbital Maneuvering Vehicle dock on the platform is included for backup servicing capability.



## PERIODIC SPACE STATION CONCEPT

Scenario: A set (probably 3 or more) of transportation "Periodic Space Stations" (PSS) are injected into special periodic orbits that pass by both Earth and Mars during their normal periods. The total period of one of these orbits is several years, thus it is necessary to have several PSS's so that each Mars-Earth opposition is covered by on short transfer between Earth and Mars in each direction.

Each PSS is injected into its periodic orbit at the best available opportunity. Several years later when the PSS passes Earth on a short passage to Mars, a vehicle launches from Earth carrying crew and consumables and rendezvous with the PSS as it passes by Earth hyperbolically. The crew transfer to the PSS for the trip to Mars. At Mars the crew leavess the PSS and in their transfer vehicle do an aerobraking entry into Mars Orbit.

Returning is similar but a PSS on a short Mars-Earth leg is used. Again the crew and consumables rendezvous with the PSS as it passes by and ride it to Earth where an aerobraking entry is again used.

**PERIODIC SPACE STATION**

**PRELIMINARY STUDY**

| TABLE I | TABLE FOR STUDY |
|---|---|
| Injection of PSS into Periodic Orbit from Earth | $C_3$ = 36 $(Km/sec)^2$ (from LEO)=4700 m/sec |
| Mission Injection to PSS from Earth | $C_3$ = 65 $(Km/sec)^2$ (from LEO)=5800 m/sec |
| Mars Encounter | $C_3$ = 93 $(Km/sec)^2$ (to/from LMO)=7400 m/sec |
| | Entry Velocity (Aerobrake) 10,930 m/sec (36,000 fps) |
| Earth Return | $C_3$ = 36 $(Km/sec)^2$ (to LEO)=4700 m/sec |
| | Entry Velocity (Aero) = 12600 m/sec (41,300 fps) |

O LEO and LMO are circular 500 Km altitude orbits.

## COMPARISON OF PSS AND STANDARD

All Propulsive Conjunction Operations

Assumption:

- O Both systems have inplace Phobos $LOX/LH_2$ production plants and an AOTV stationed at Mars.
- O Freight is handled separately.
- O AOTV's and Drop Tanks are used.
- O Only steady state ops are considered (i.e., no penalty for initial PSS injection is assumed).

For the conjunction missions a 55 ton mission module is used.

Conjunction Mission Scenario:

The mission module with crew is boosted trans-Mars using 2 OTV's and 2 Drop Tanks (50 ton prop each, 5 ton inert each). The 2nd stage remains with the MMM and deboosts the whole unit into a 24 hour ellipse at Mars. The AOTV and attached 5 ton OTV MM then transfers to Phobos for fueling and crew transfer.

Return is with 2 AOTV's and one Drop Tank.

The Drop Tank is carried on to Earth for reuse.

At Earth the Mars Mission Module is deboosted propulsively into Low Earth Orbit for reuse in next mission.

Equipment and Mass for Each Option/Mission

| | PSS | Conj. Standard |
|---|---|---|
| Launched to LEO | 149 ton (incl 2-7.5 ton Drop Tanks) | 215 tons (incl 2-5.5 ton Drop Tanks) |
| Prop at Mars | 234 tons | 175 tons |

Other Factors

PSS - require High Velocity Aero entrys of manned units.

PSS - requires Hyperbolic rendezvous (twice/mission) of manned units.

Conj/Stand - provides habitat during Mars orbital operations.

Conj/Stand - equipment can be incorporated into earlier setup missions. More evolutionary. Less risk.

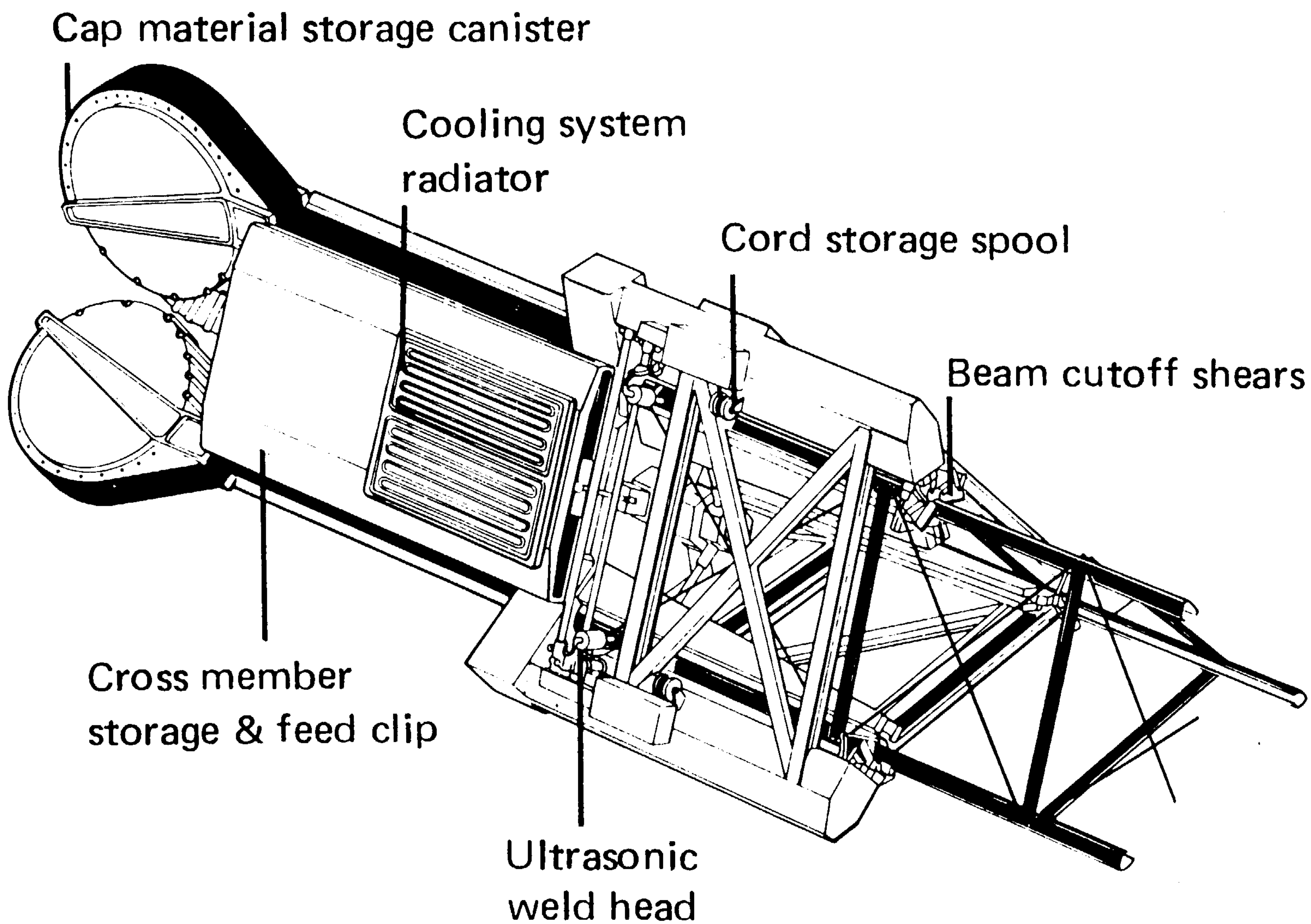
## BEAM BUILDER MACHINE

## SKETCH NO. 24a

The construction of large structures in space will most likely involve several highly automated techniques. Large systems will probably utilize regular, uniform cross-section structural members to facilitate construction. An element of an automated operation could include a beam builder device - a concept of which is illustrated in Sketch No. 24.

The beam builder fabricates structural beams on-orbit employing a system adapted from the sheet metal roll-forming industries. A light-weight, rigid structure is formed as material (aluminum or graphite/thermoplastic) pullled from tightly wound rolls contained in pulled storage cannisters, pressed into a triangular cross-sectional shape, with cross members automately fed from storage and ultrasonically welded into place. Shears at the end of the unit cut beams when required. Cooling is provided by installed radiators.

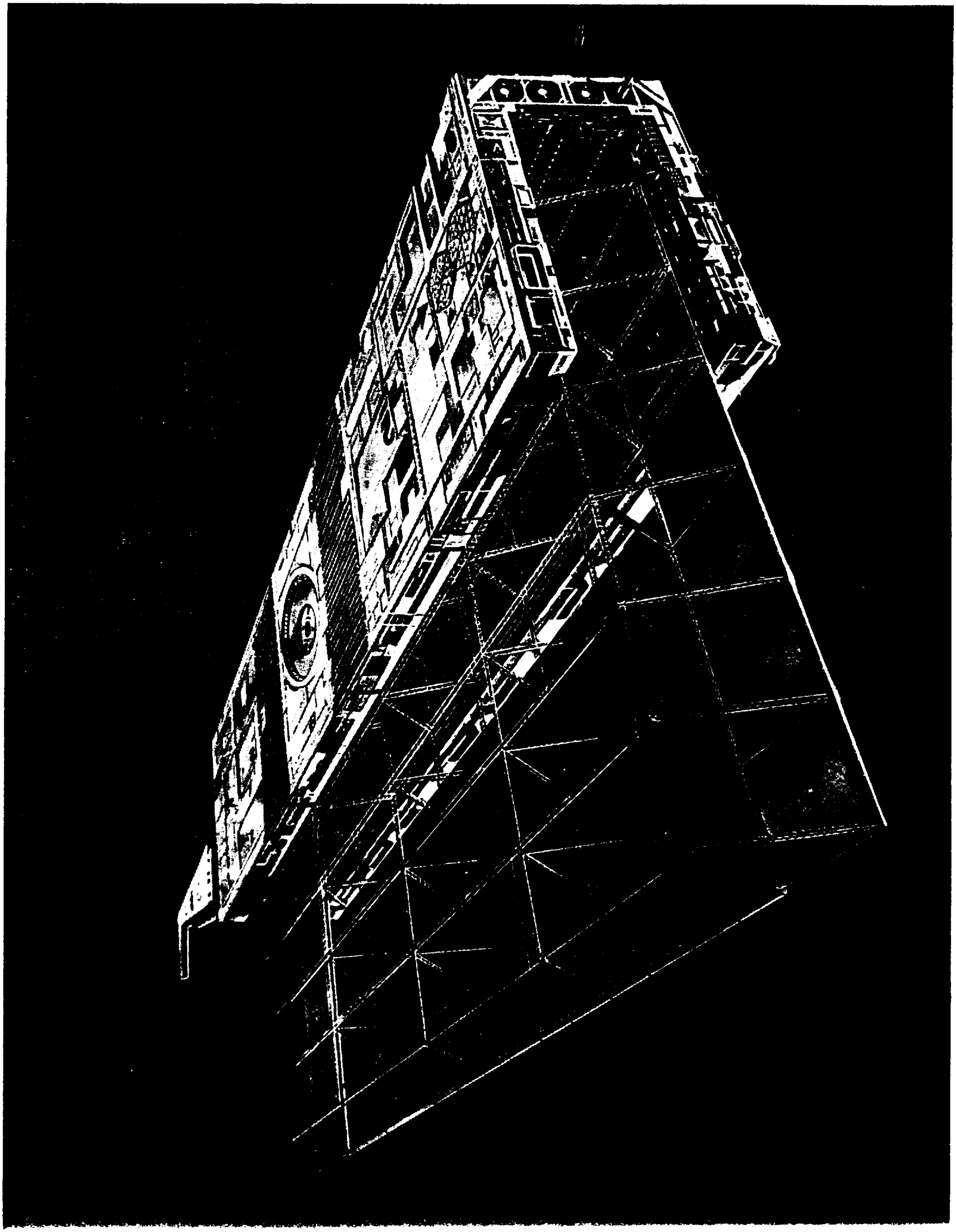
Beam construction ▼ Automated beam builder



## SPACE CONSTRUCTION FACILITY

### SKETCH NO. 24b

Sketch No. 24b shows a concept for construction of large space structures utilizing the beam builders in Figure 24a. Such a manufacturing plant in space could be used for construction of large space structures such as the Solar Power Satellite or the Earth-Mars Periodic Stations.



Sketch # 25a, 25b

Subject: lunar habitats

Sketch #25a,b A Layout of Space Station modules for an early Lunar Base

The initial Lunar Base will be very "Earth dependant" and will rely on delivery of most of its elements directly from the Earth. The initial habitation elements will utilize Space Station inheritance and will be arranged as shown to minimize the delivered weight to the Lunar surface. The interconnect modules that provide egress to the Lunar surface must be specifically designed to provide a washdown and suit storage area. All other systems and subsystems, including structure, are compatible for direct application to the Lunar surface.

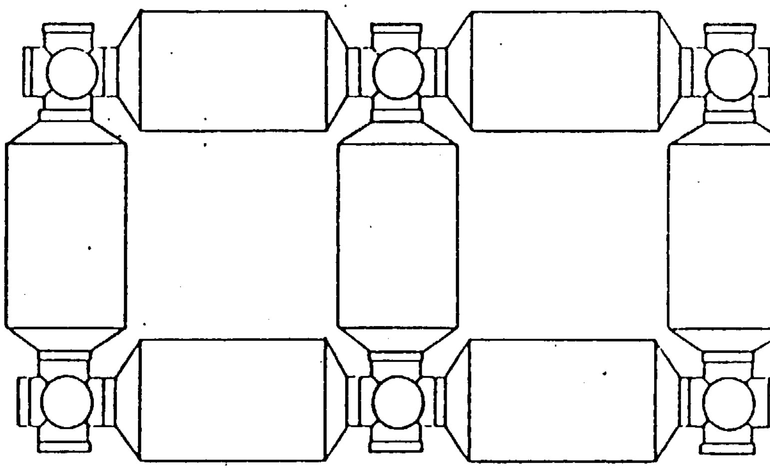
S87-70425-9



# LUNAR BASE MODULE ARRANGEMENT STUDY

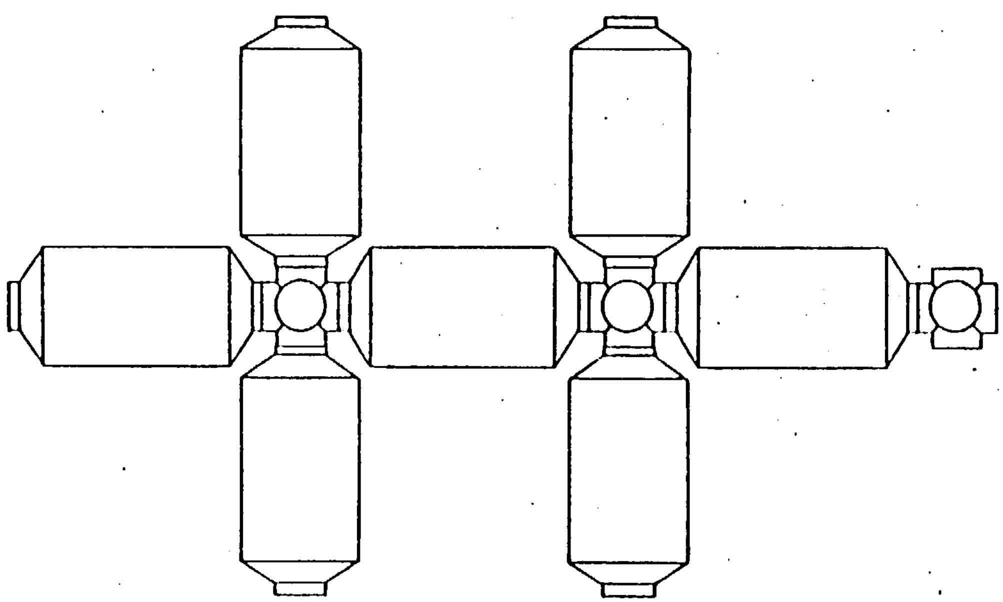
A

4 IM'S FOR FIRST 4
MODULES
+
2 IM'S FOR EACH 3
ADDITIONAL
MODULES



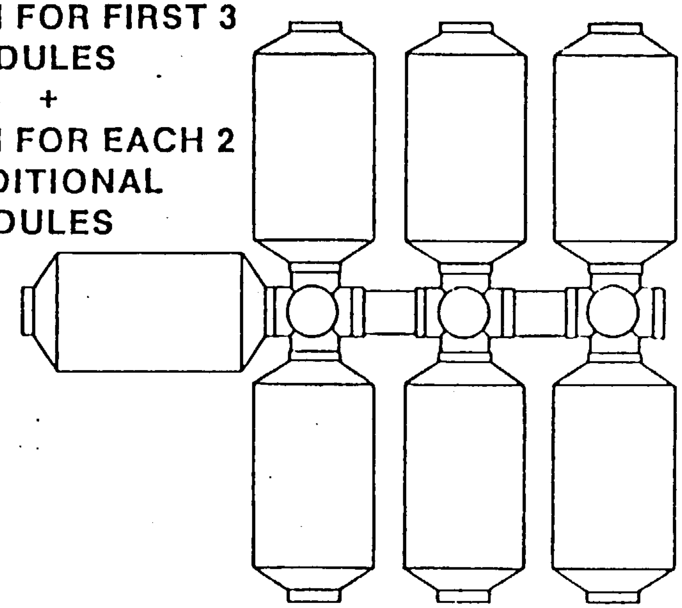
B

1 IM FOR FIRST 4
MODULES
+
1 IM FOR EACH 3
ADDITIONAL
MODULES



C

1 IM FOR FIRST 3
MODULES
+
1 IM FOR EACH 2
ADDITIONAL
MODULES

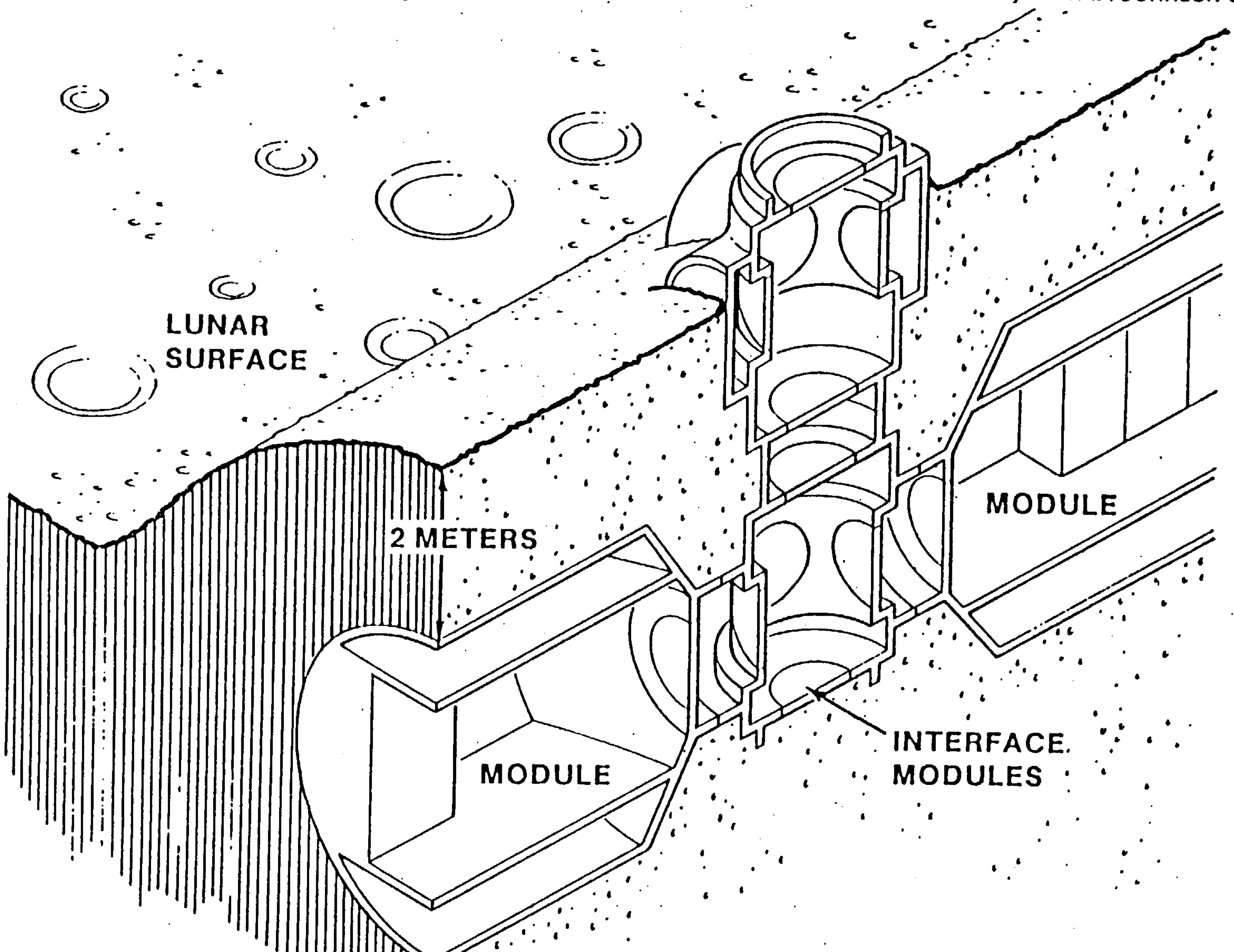


SKETCH 25 b.



## SHIELDING REQUIREMENTS



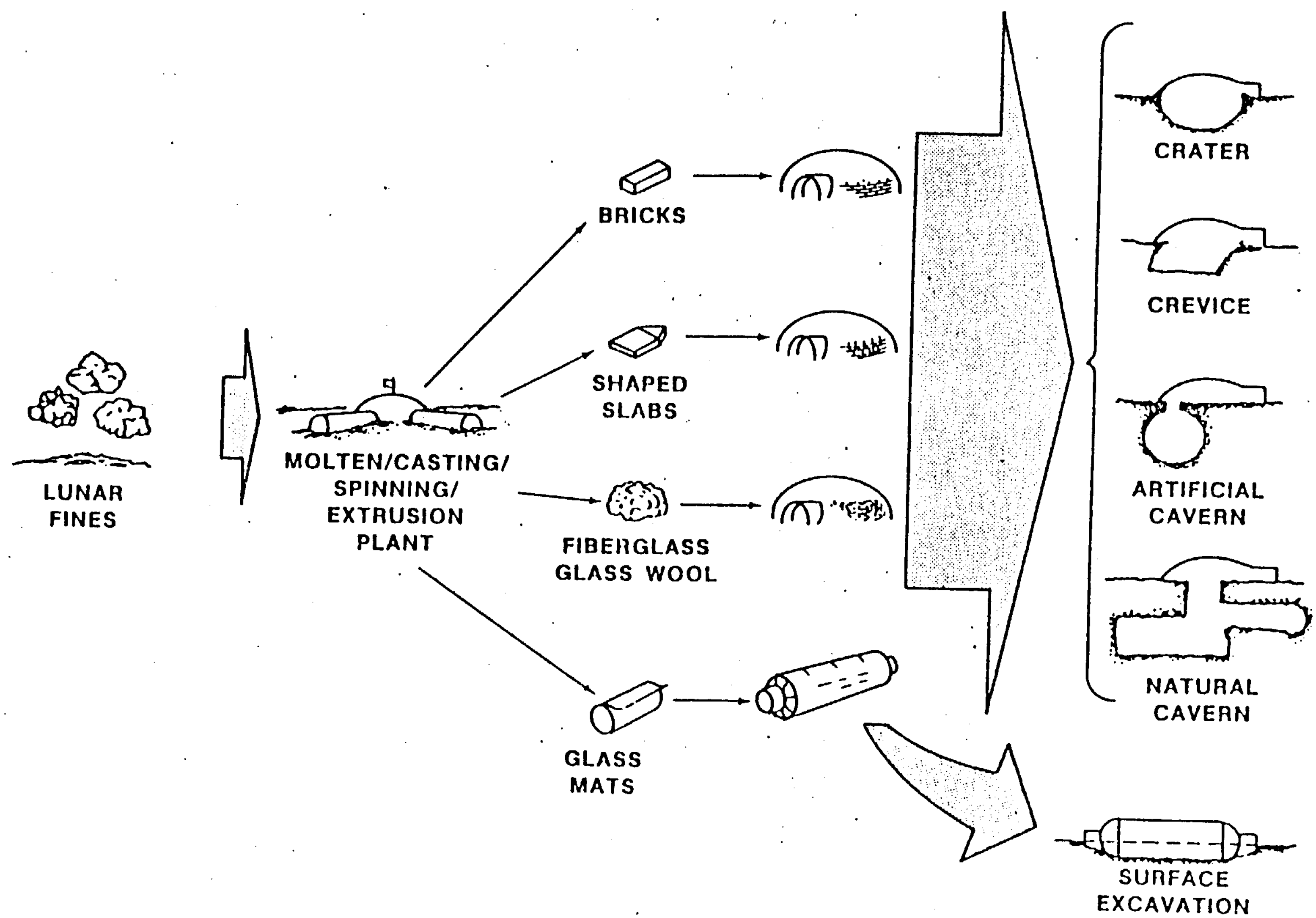



G12

Sketch #26 Options for advanced Lunar habitation

For permanent manned occupancy at an advanced Lunar Base, our studies to date have shown that it is mandatory that the umbilical cord to the Earth be severed. This will require the development of concepts that utilize in-situ resources. This sketch demonstrates several options for utilizing Lunar resources for habitation.

## LUNAR DERIVED CONSTRUCTION MATERIALS



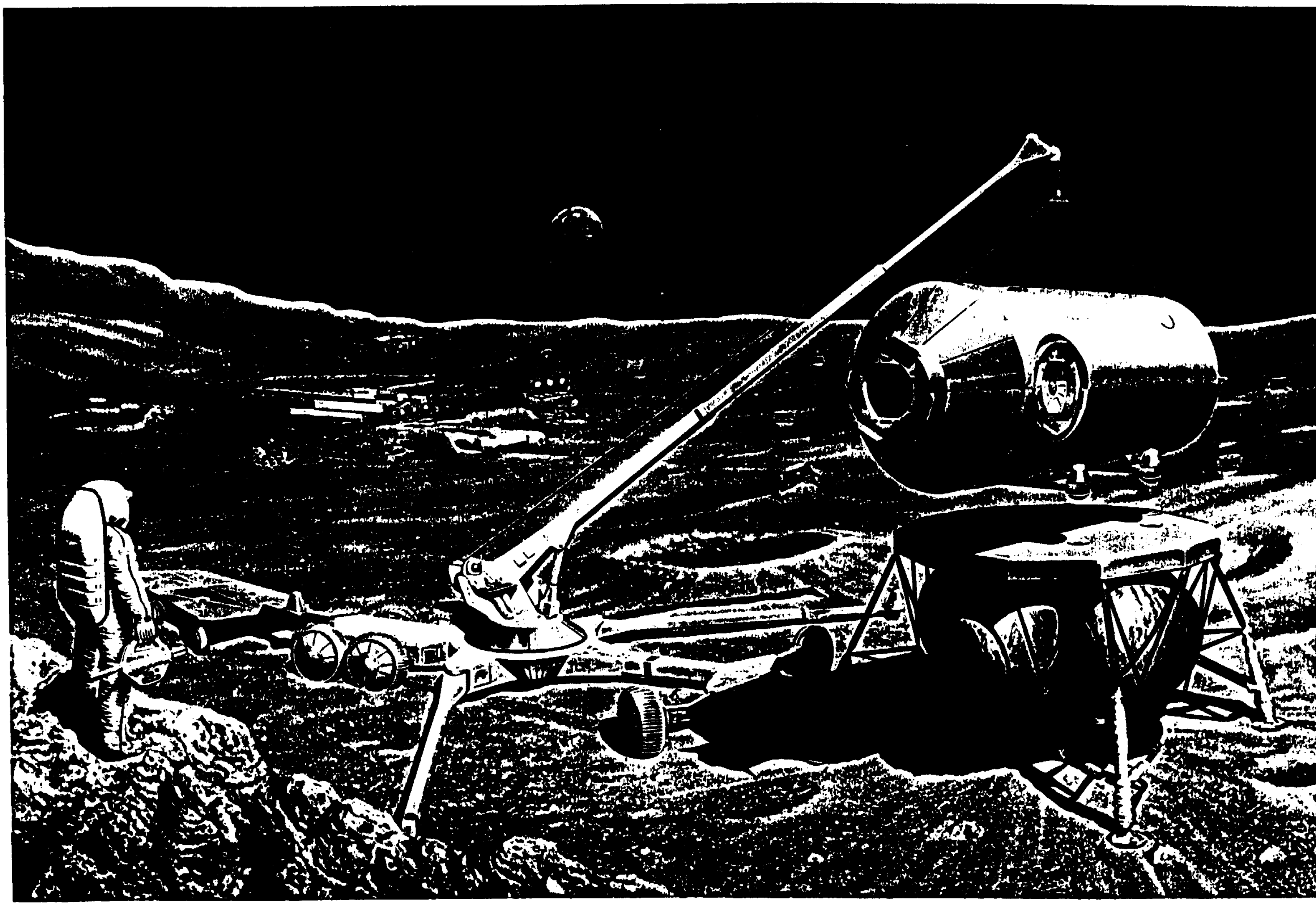
Sketch #27 An interim Lunar Base

This artist's painting shows an interim Lunar Base with a Lunar Crane unloading one of the last habitation modules for the Lunar Base. In the background are the other modules partially covered with Lunar regolith for protection from Solar flares. The LLOX plant is fully operational at this time and is ready to support vehicle operations. The Lunar lander in the foreground is an expendable version that will be replaced with a reusable version now that the LLOX plant is operational. The Lunar landscape is dotted with other discarded expendable landers. It would be wise that the structure of these vehicles be constructed of materials that are high in elements that are defficient on the moon, such as carbon for reprocessing later to support agriculture. The engine subsystems and avionics will be recycled for use in the reusable Lunar lander. In the far background, the flower-petal shapes are the radiators from SP100 derivative nuclear power plants. Nuclear power has many advantages over Solar power if both must be delivered from the Earth. Advanced Lunar Bases that have significant support facilities could overcome this advantage through the manufacture of components for Solar power and the needed energy storage systems using Lunar resources.

National Aeronautics and
Space Administration

S84-43855

Lyndon B. Johnson Space Center
Houston, Texas 77058



Sketch #28

Subject: Lunar Radiotelescope

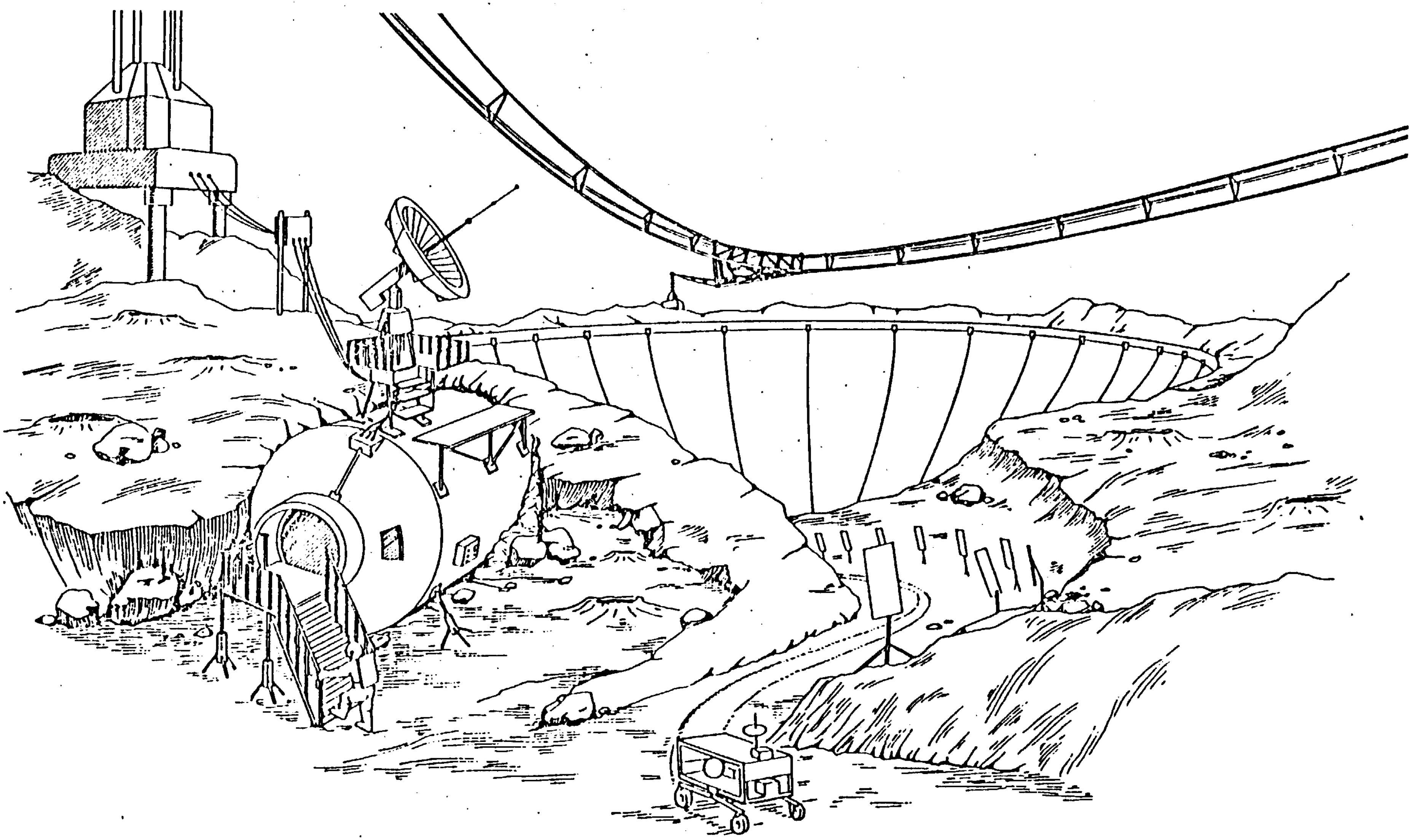
The absence of an atmosphere around the Moon makes it an excellent space platform for astronomical studies of all kinds. A radiotelescope on the far side of the Moon has often been recommended as part of the scientific instrument complement at a Lunar Base. In this case, the Moon's bulk provides a shield against terrestrial radio noise which is the evergrowing bane of deep space observations. Low frequency radio observations are not possible from the Earth's surface due to the interference from the ionsphere. A Lunar radiotelescope making simultaneous observations with a terrestrial one could constitute a high resolution interferometer having a 400,000 km baseline. Although a lunar radiotelescope is frequently depicted as a parabolic dish in a conveniently parabolic Lunar crater, the actual instrument may well be a phased array of dipole antennas located just beyond the Lunar limb.

LSR LUNAR SURFACE RETURN

84-00791 NASA

## RADIO TELESCOPE

Lyndon B. Johnson Space Center

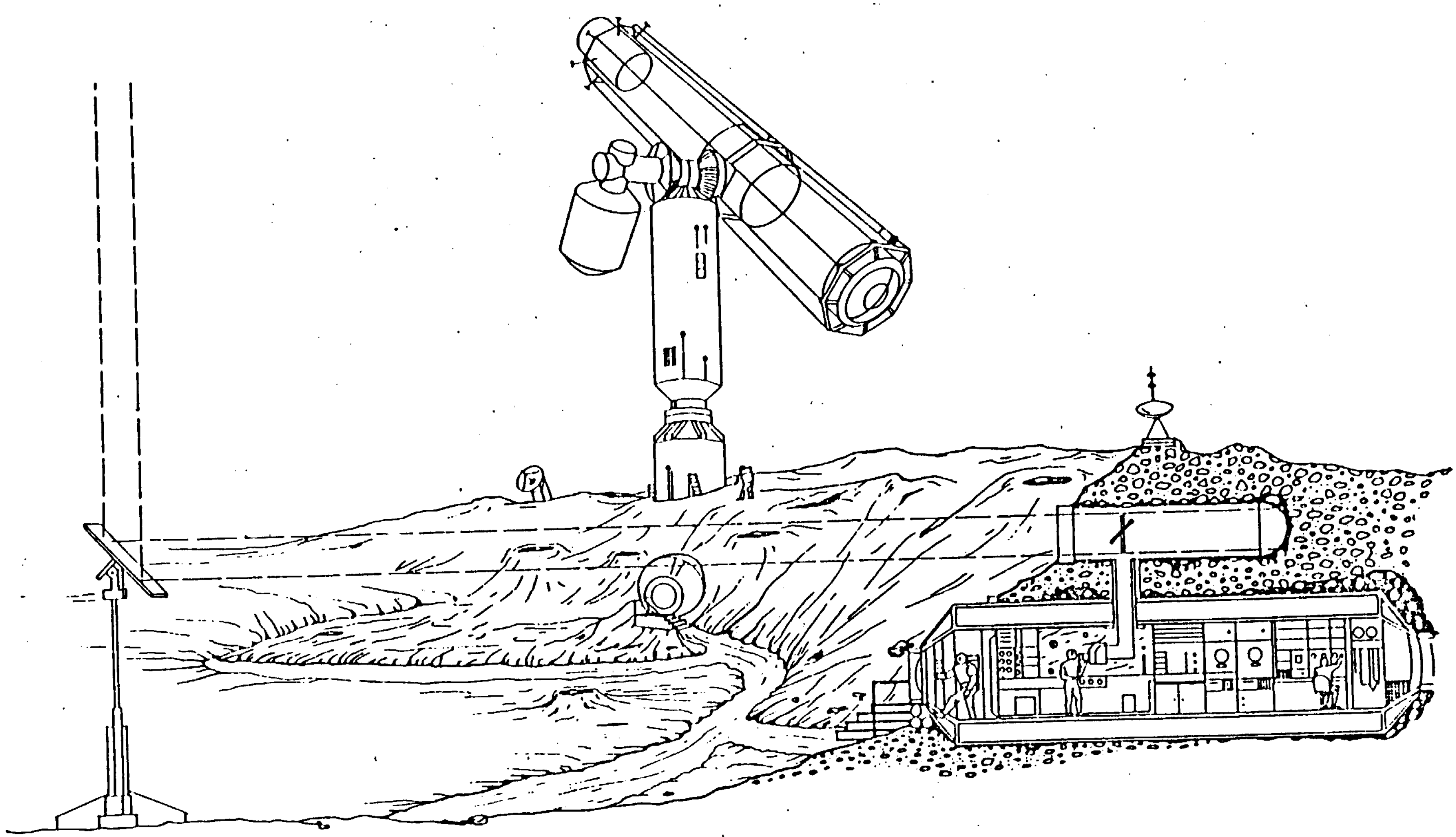


B14

Subject: Sketch # 29 Astronomical Telescope

X-ray astronomy, gamma ray astronomy, cosmic ray monitoring, infrared observations, and traditional optical observaions are all candidates for a Lunar scientific base. Many of these activities are pursued in Earth orbit now, but the Lunar surface can offer its own advantages for certain cases. Orbiting telescopes can have difficulty making sensitive observations which require long, continuous observation times, because the Earth may occult an object during an orbit, and the Sun must be avoided by a wide margin. On the Moon, the Lunar horizon can be used as an occulting disk for observations near the Sun, and the Moon's leisurely rotation allows long integration times. At a manned base, consumables such as cryogenic coolants can be replentished. A planetary surface also provides a stable platform for accurate pointing.

## OBSERVATORY



Sketch #30 - Short Range EVA Rover

1) ~~The first~~ is a short range EVA rover (life support suits required for crew) for near-base operations. A significant amount of Apollo inheritance is assumed. This vehicle would be capable of carrying a crew of two, and a payload of approximately 600 kg. for a distance of 50 km. Note that in an emergency, this payload could consist of an extra two crew persons. Sketch #30

~~2) (this text to be provided by Paul Phillips/EEL)~~

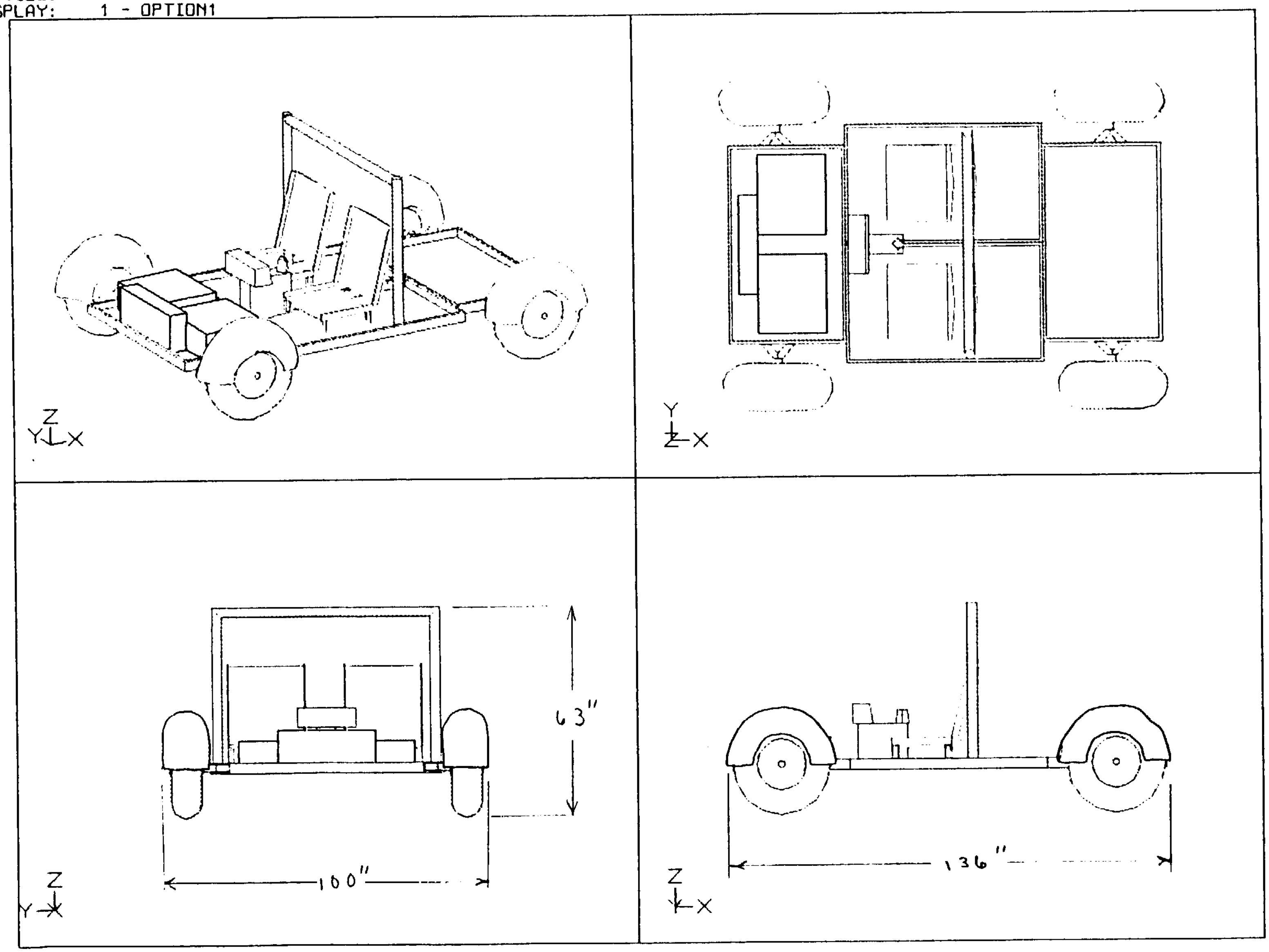
EVA (Lunar) Rover

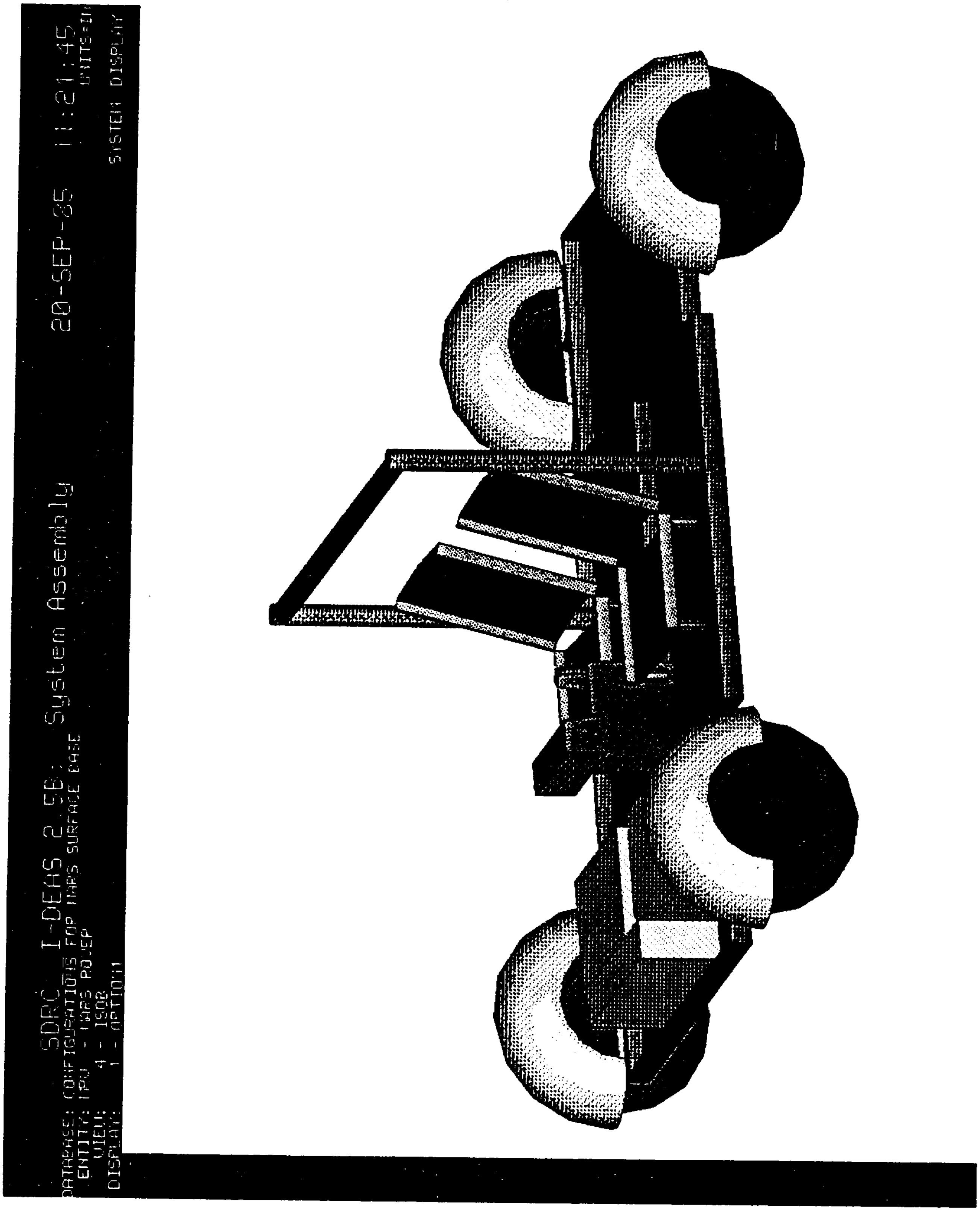
SDRC I-DEAS 2.5B: System Assembly 20-SEP-85 16:17:24

UNITS=IN

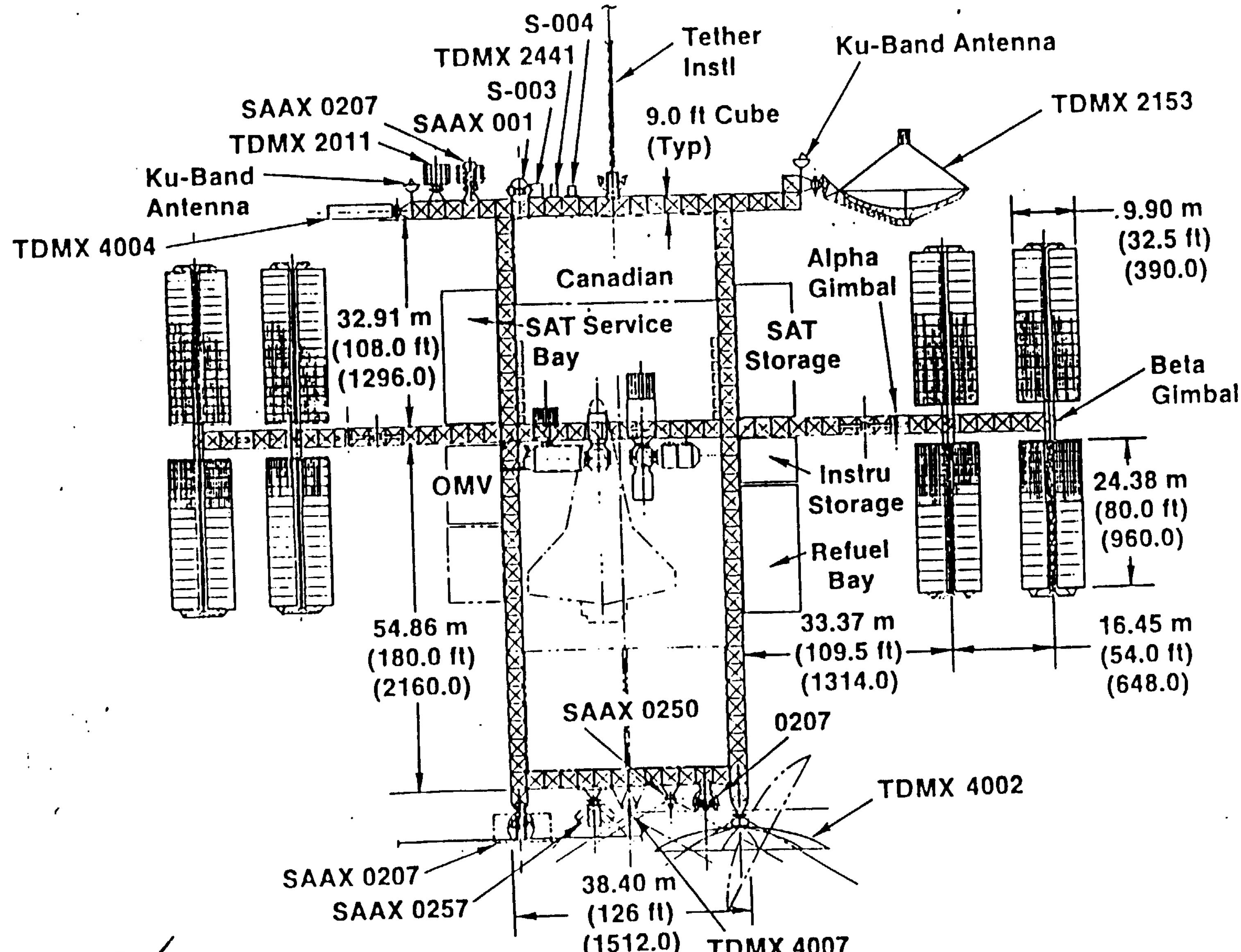
DATABASE: CONFIGURATIONS FOR MARS SURFACE BASE
ENTITY: MRU - MARS ROVER
VIEW: 17 - RFRO
DISPLAY: 1 - OPTION1

SYSTEM DISPLAY




SDRC I-DEAS 2.5B: System Assembly
20-SEP-85 11:21:45
UNITS=IN
DATABASE: CONFIGURATIONS FOR MARS SURFACE BASE
VIEW: 4 - ISOB
DISPLAY: 1 - OPTION
SYSTEM DISPLAY

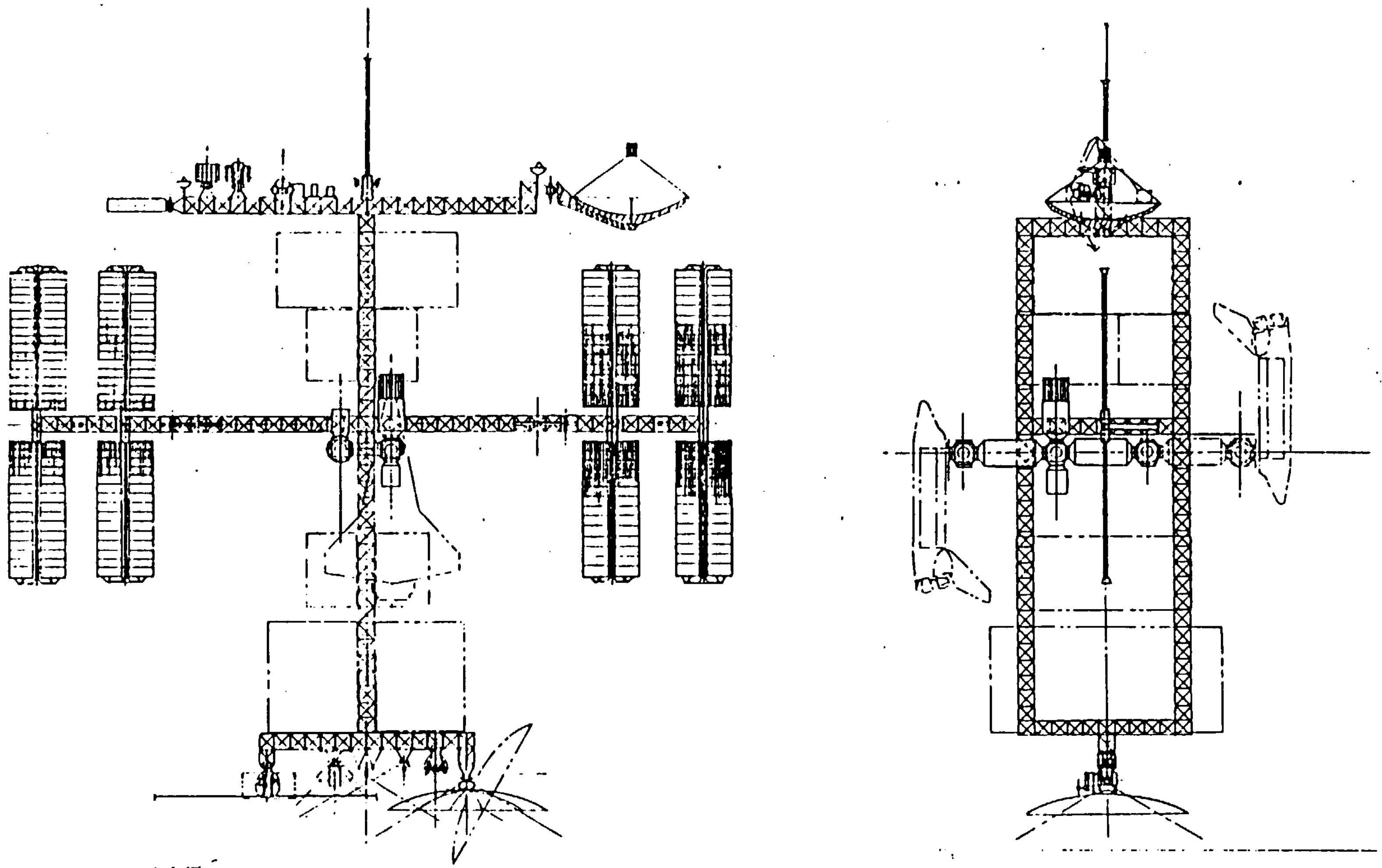
# DUAL KEEL — 1992




MCDONNELL DOUGLAS CORPORATION | IBM | Honeywell | RCA | Lockheed — SPACE STATION PROGRAM

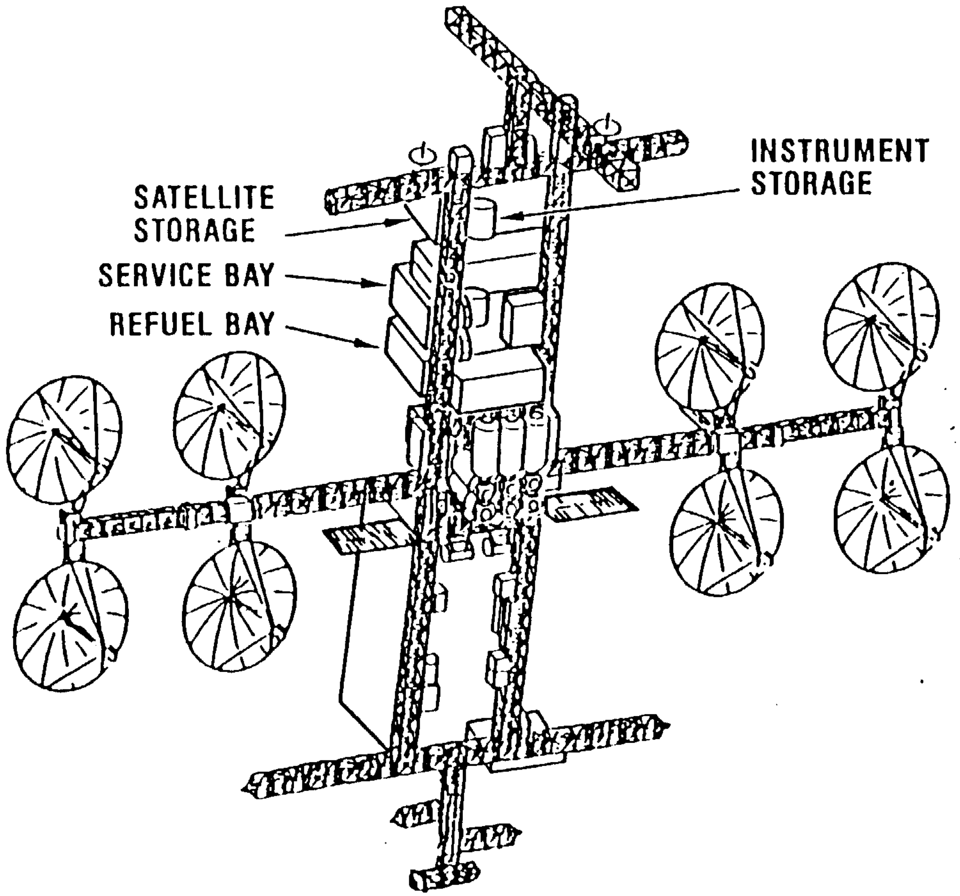
VHJ656

# KEEL PLANE IN ORBIT PLANE



# Full Dual Keel Provides Operational Flexibility

## FULL DUAL KEEL MID TERM CONFIGURATION

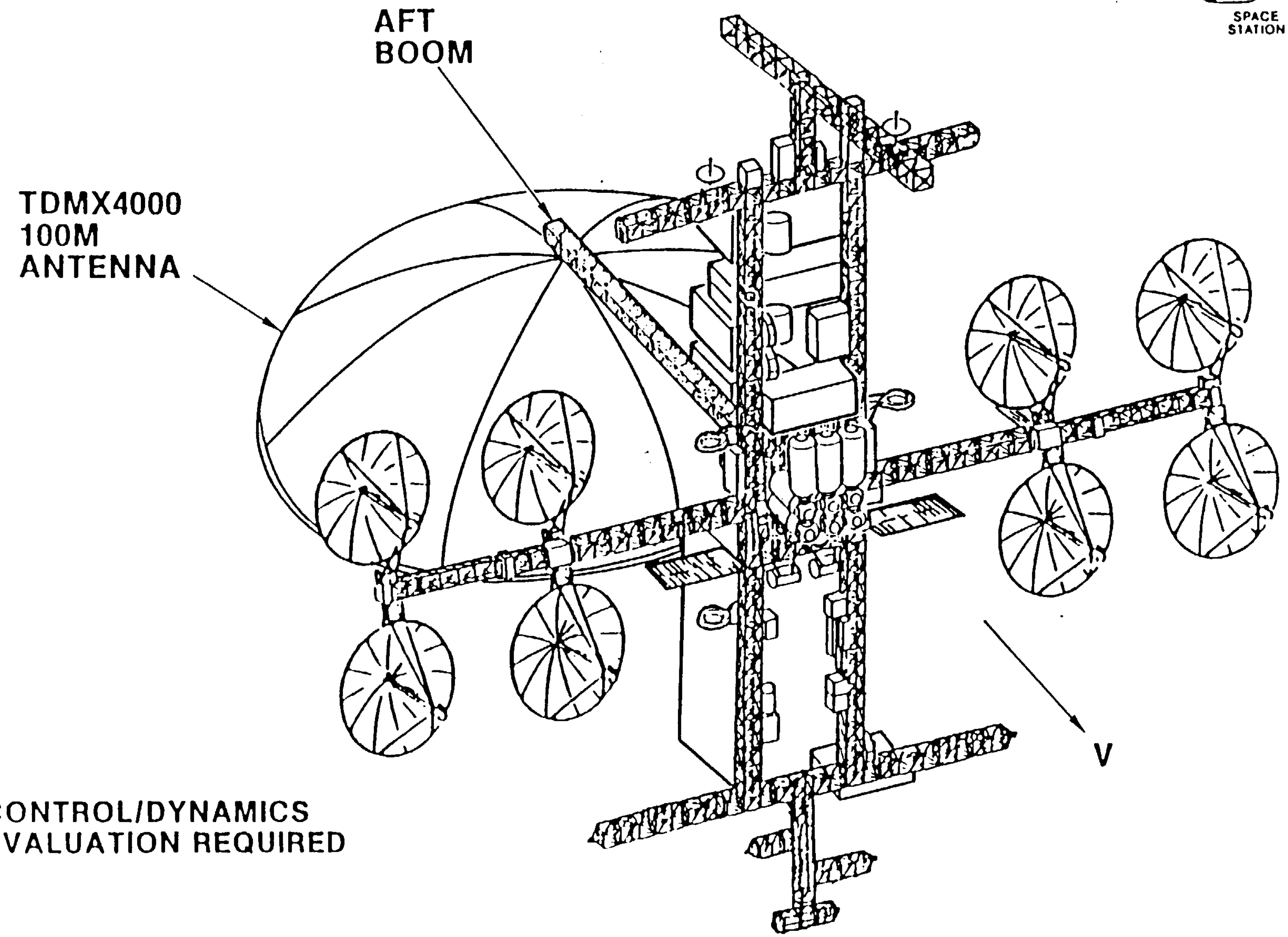



CHARACTERISTICS:

- ENHANCED ACCESSIBILITY/OPERATIONS
- FULL USER DATA BASE KEEL MOUNTED ACCOMMODATIONS
- CENTRALLY LOCATED MODULES ACCOMMODATE MICRO "G" ENVIRONMENT
- ACCOMMODATES WP3 SERVICING FACILITIES

## ENHANCED ACCESSIBILITY/OPERATIONS

# Large Space Structures Can Drive Space Station Design

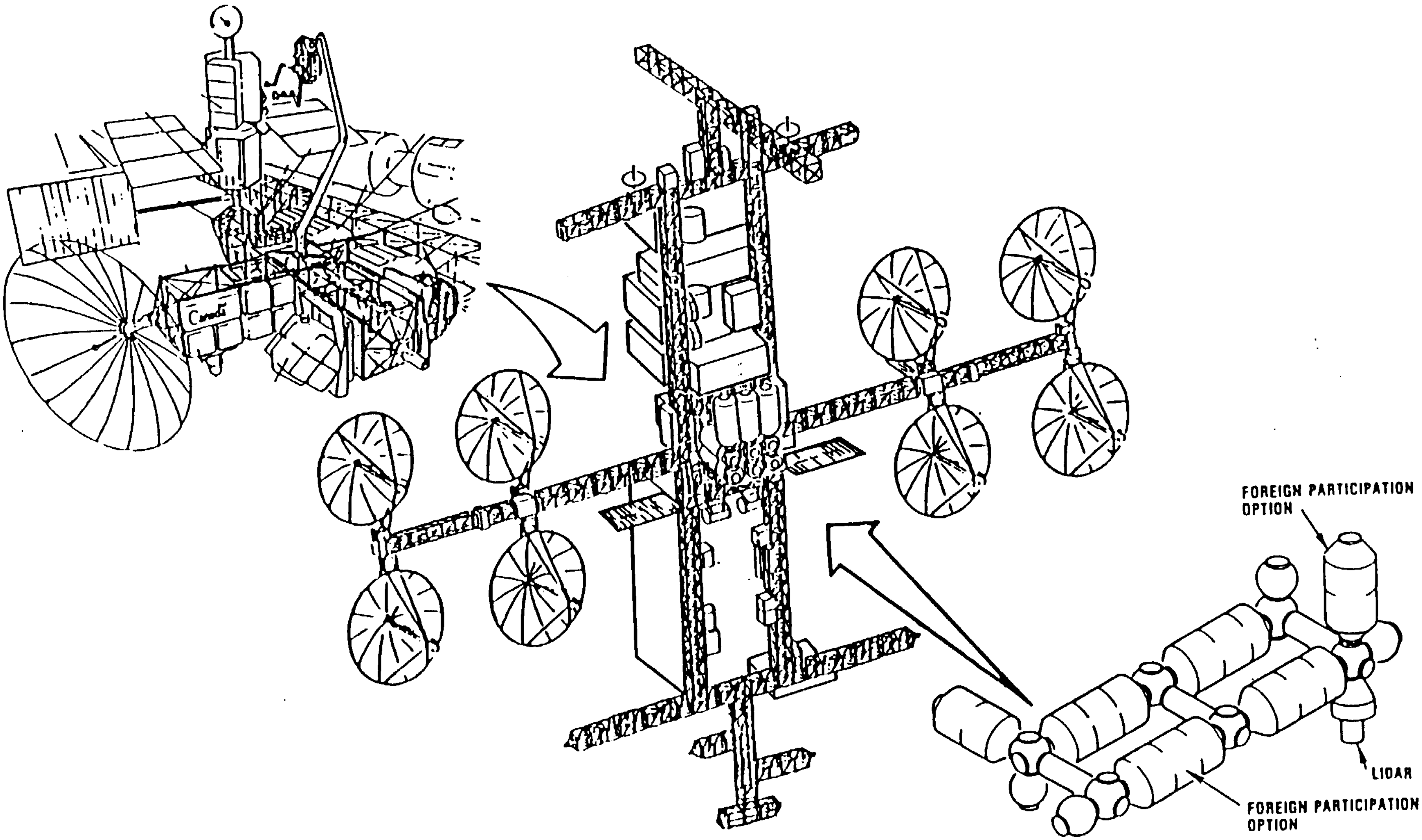



• CONTROL/DYNAMICS EVALUATION REQUIRED

# International Participation Accommodated

SPACE STATION

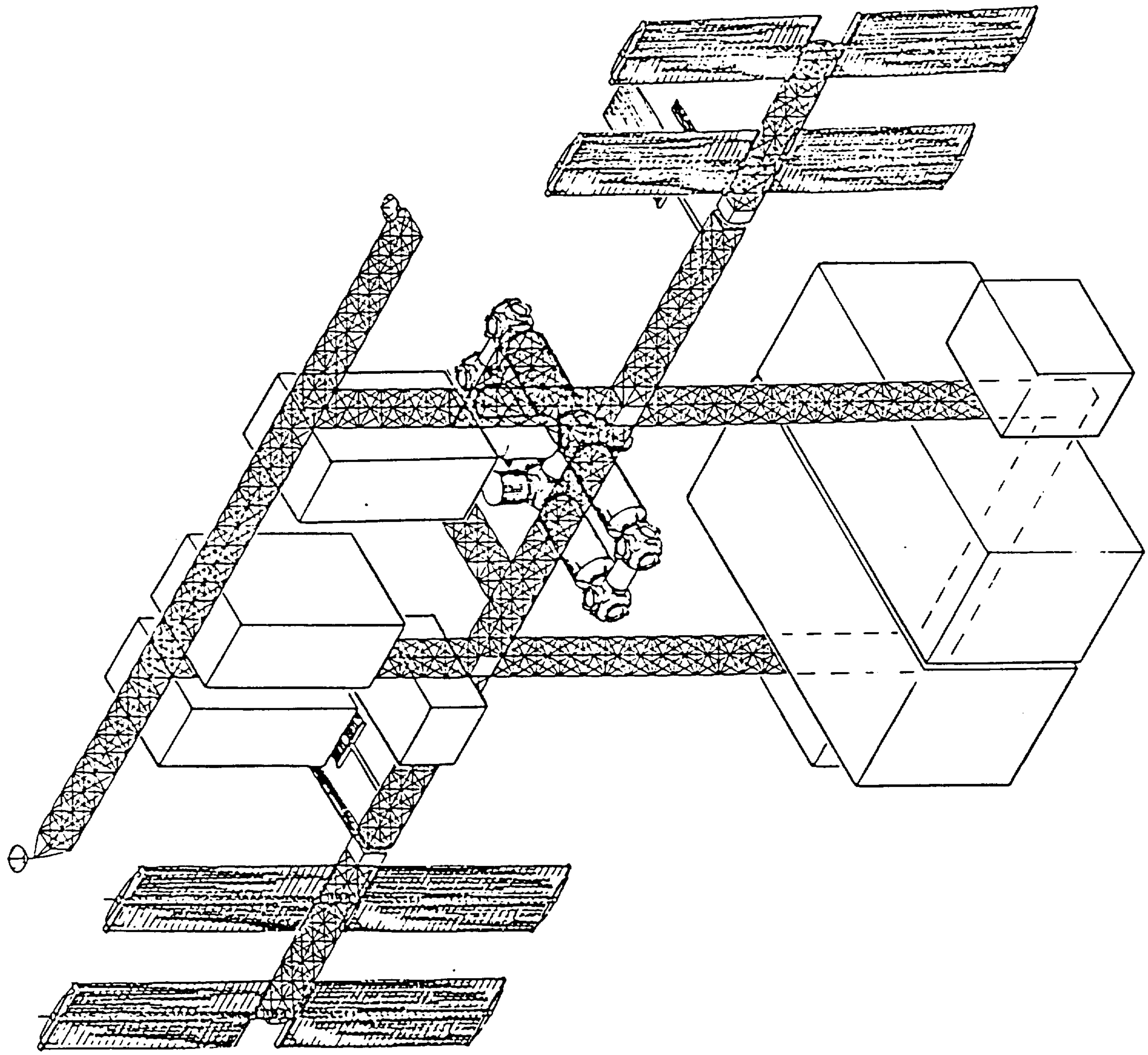
## EXTERIOR PAYLOAD ACCOMMODATIONS




PRESSURIZED LABORATORIES

Rockwell International
Space Station Systems Division

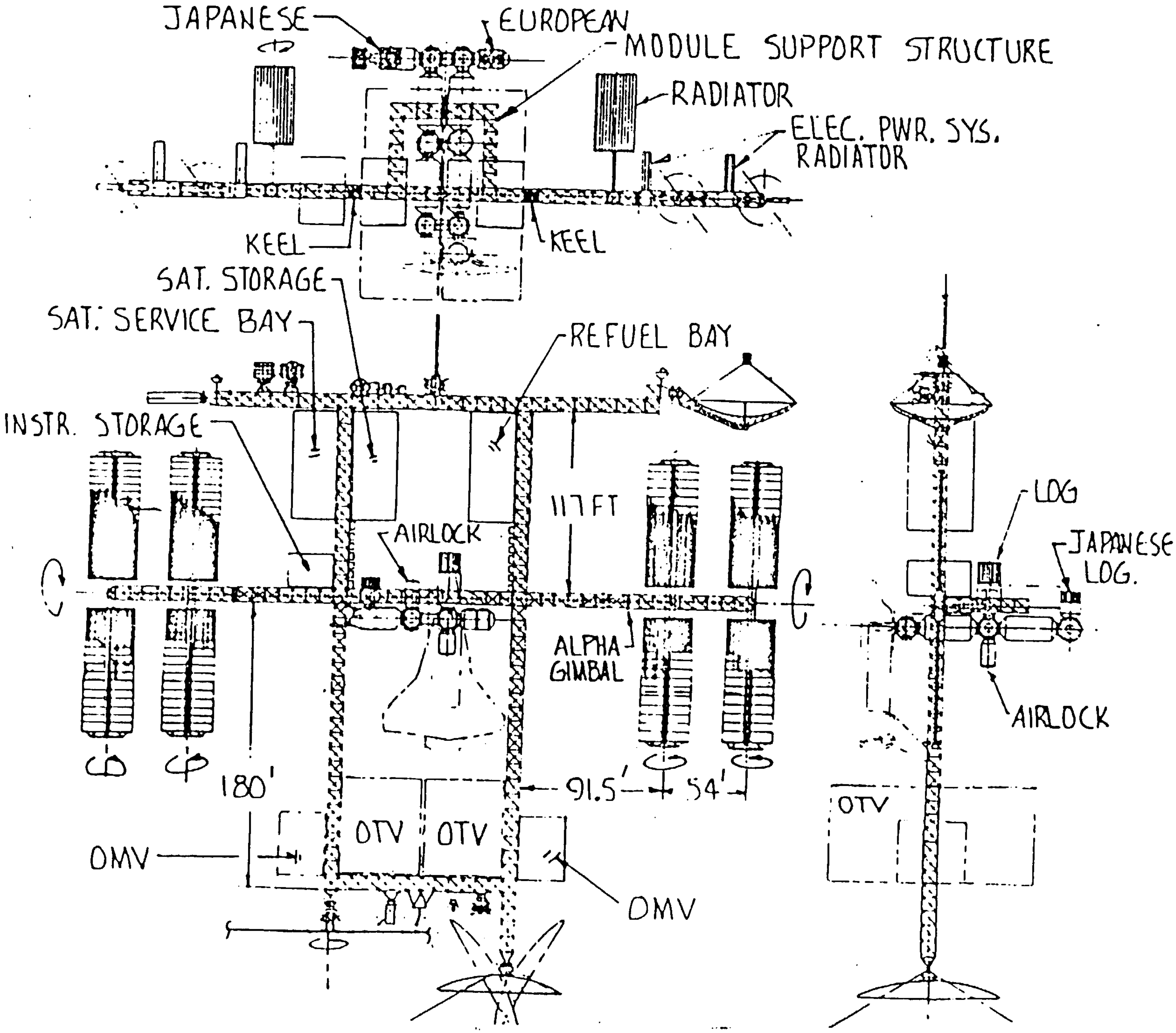
85SSS165777A





C-2

# DUAL KEEL - 1992



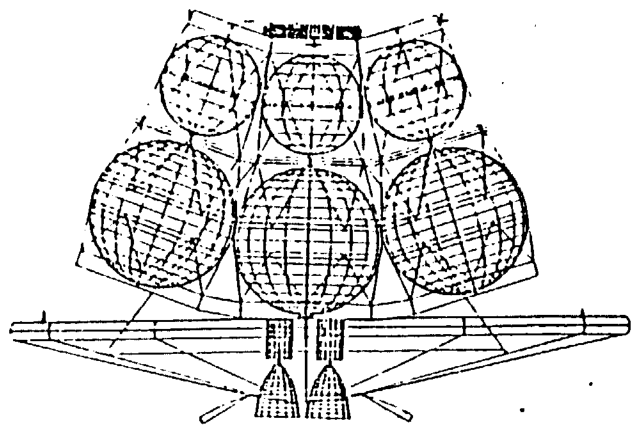
## ORBIT TRANSFER VEHICLES

The Agency is currently in a definition phase for the orbit transfer vehicle, and therefore it is difficult to give a good representation of what its configuration ought to be at this time. However, studies to date have, to some extent, defined the pertinent performance parameters. The sketches attached show several optional configurations for the OTV. The most promising configurations are geometrically "off-center" to generate aerodynamic lift when flying in the atmosphere. This will allow the vehicle to correct for day-to-day variations in the atmosphere which are unpredictable at this time. Pure drag configurations such as the ballute have the advantage of lightest weight and greatest flexibility but pose a significant design challenge to be able to accomodate the drag variations needed to successfully navigate the atmosphere.

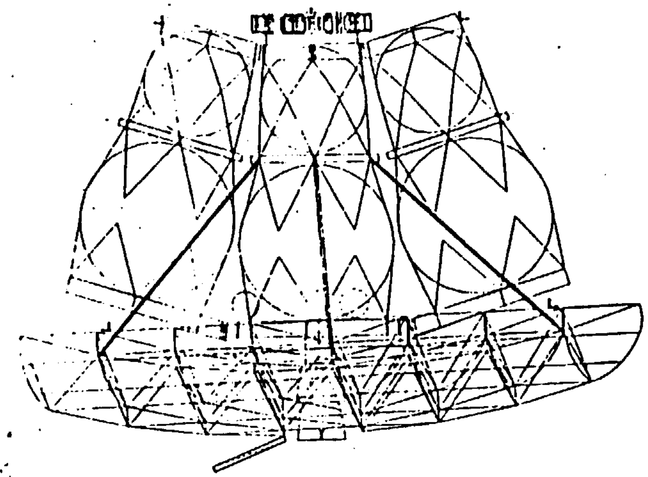
The "turtle" configuration shown is a point design that has the performance characteristics necessary for Lunar delivery, and also has enough performance for the various other missions when auxiliary propellant tanks are utilized. The principal features are aerodynamic lift (L/D=.3 - .6), 42mt internal propellant load and 30,000lbs thrust. All other features shown in the sketch are speculative. In particular, the thermal protection system (TPS) shown is state-of-the-art Shuttle type tiles. Other TPS concepts, such as fabrics, would be lighter in weight. This particular configuration is utilized in all of our sketches only as a reference configuration although other competive configurations may have better performance.

GENERAL DYNAMICS
Space Systems Division

# AEROBRAKE DESIGN CONCEPT TRADE STUDY
## Space-based S-4C OTV



Strut Supported Rib



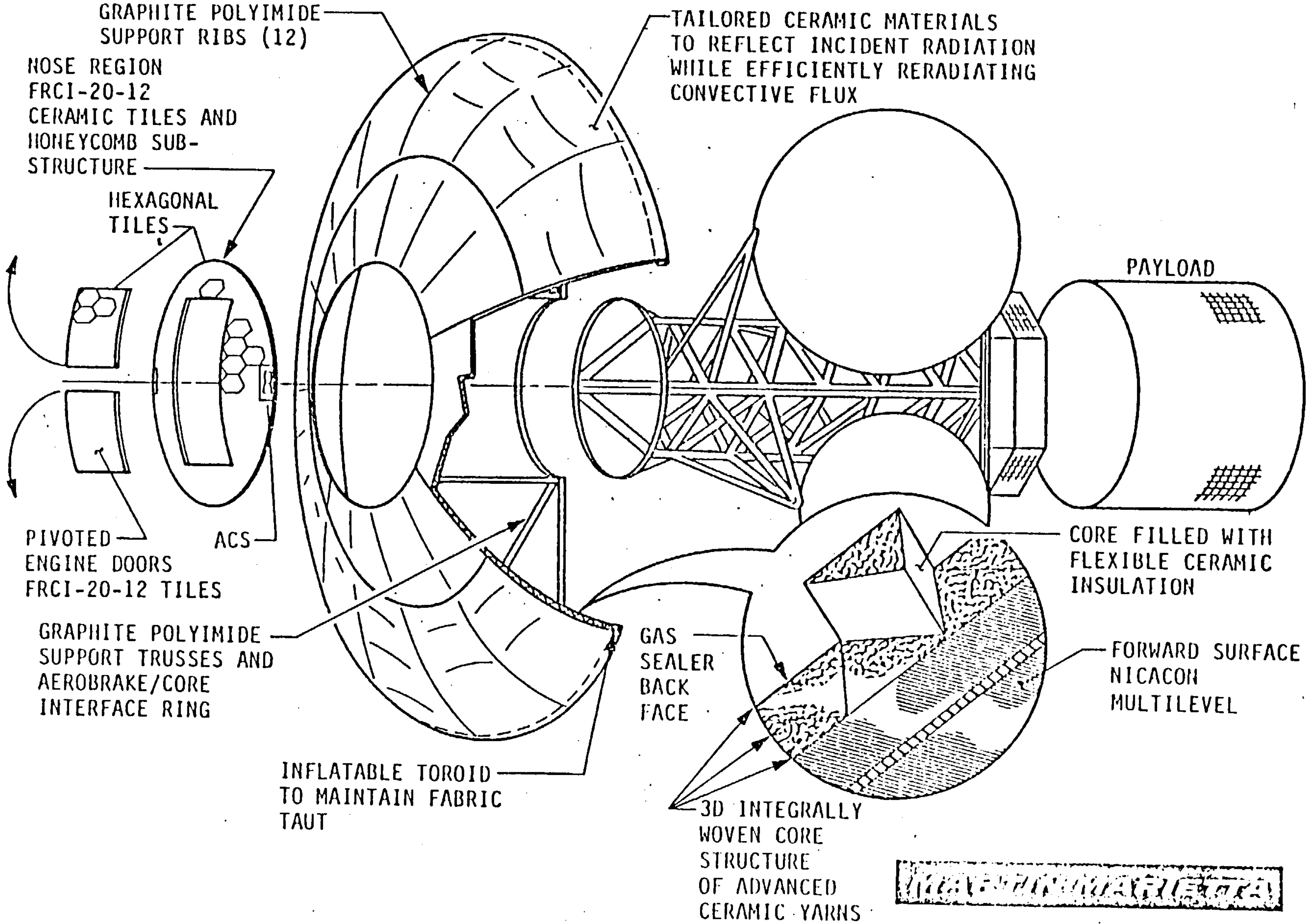
Strut Supported Geotruss

| | | |
|---|---|---|
| Sizing criteria - Vehicle<br>- Brake | 7,500 lb manned mission<br>15° AOA impingement | |
| Operations | Full EVA assembly/<br>20 major elements | Automatic/EVA assembly<br>of door & six struts |
| Aerobrake weight - lb | 3,230 | 2,690 |
| - Structure | 1,400 | 960 |
| - TPS | 1,410 | 1,380 |
| Usable propellant - lb | 57,430 | 55,680 |
| Aerobrake/aeroentry | 0.152 | 0.130 |

**SBOTV - Geotruss has lowest weight & least operations cost**

30075545-83

# OTV RIGID/FLEX TPS AEROBRAKE

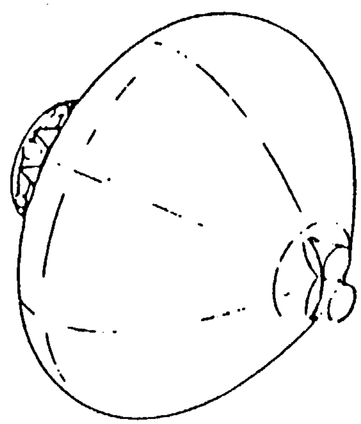


Phase A
OTV

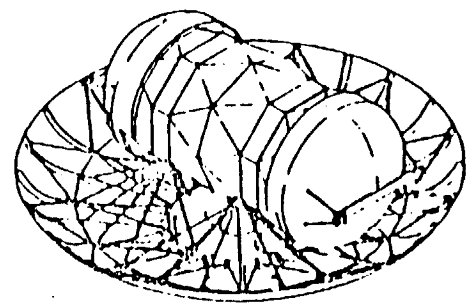
# SB OTV Aeroassist Trade
## Concept Features

OTV 728

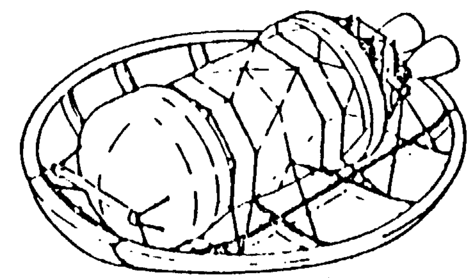
• ALL SIZED FOR GEO MAN SORTIE (7.5 K LBS RT)



BALLUTE BRAKE



LIFTING BRAKE



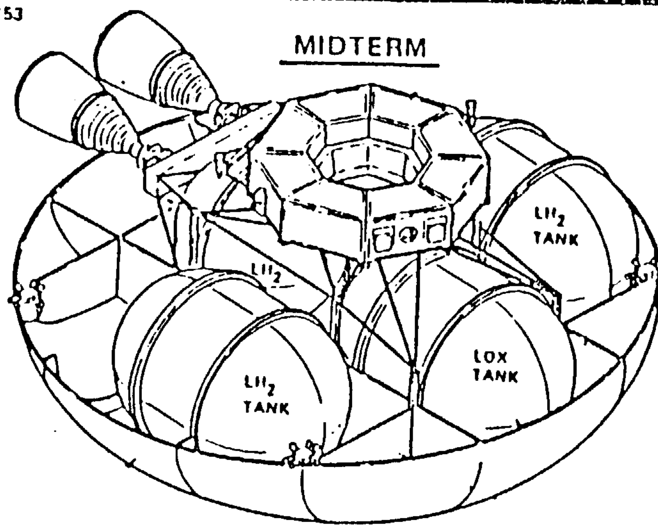
SHAPED BRAKE

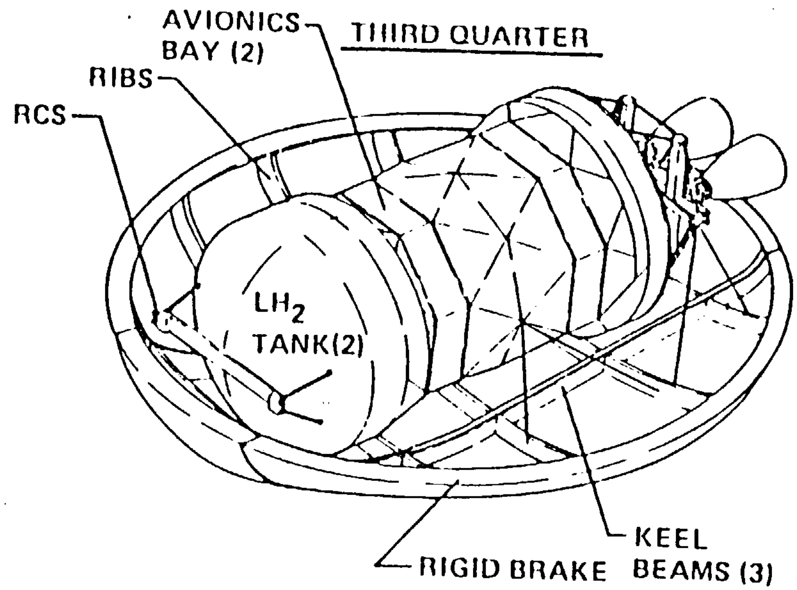
| | BALLUTE BRAKE | LIFTING BRAKE | SHAPED BRAKE |
|---|---|---|---|
| • BRAKE | | | |
| • DIAMETER (FEET) | 50 | 42 | 44 |
| • USES | BALLUTE (1)<br>HEAT SHIELD (20) | TPS (5)<br>HEAT SHIELD (20) | HEAT SHIELD (20) |
| • WEIGHT (LBS) | 2712 | 3276 | 3608 |
| • B/W TEMP ($^oF$) | 1500 | 600 | 600 |
| • OTV DRY WEIGHT (LBS) | 9189 | 9947 | 10314 |
| • L/D | --- | 0.12 | 0.23 |
| • $W/C_DA$ | 9.16 | 10.3 | 12.0 |
| • PEAK HEATING ($BTU/FT^2/SEC$) | 41.1 | 35.7 | 36.0 |

Phase A
OTV

# SB OTV Shaped Brake
# Third Quarter Concept Update

OTV-753




## KEY CHANGES

| Midterm | | Third Quarter |
|---|---|---|
| CIRCULAR (40' DIA.) | SHAPE | ELLIPTICAL (44' X 36' |
| 11.7 | $W/C_DA$ | 12.0 |
| 13–15 (4 TANKS, 7–9 SHELL, AVIONICS, ENGINES) | MAJOR ORBITAL ASSEMBLIES | 4 (PROPUL/AVIONICS AND 3 SHELL UNITS) |
| 11 | FLUID/ELECTRICAL CONNECTIONS | 0 |
| AEROSHELL PROVIDES BACKBONE OF SYSTEM | STRUCTURE | PROPUL/AVIONICS MODULE PROVIDES BACKBONE |
| 12,400 | DRY WEIGHT (LBS) | 10,315 |
| 68,700 | USABLE PROP. LOAD | 67,200 |



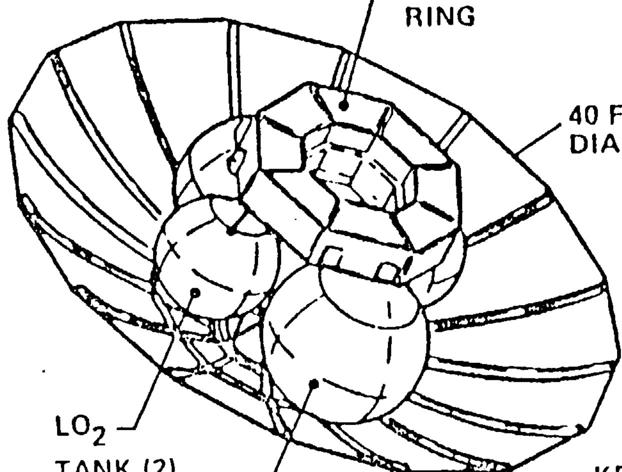
BOEING

Phase A
OTV

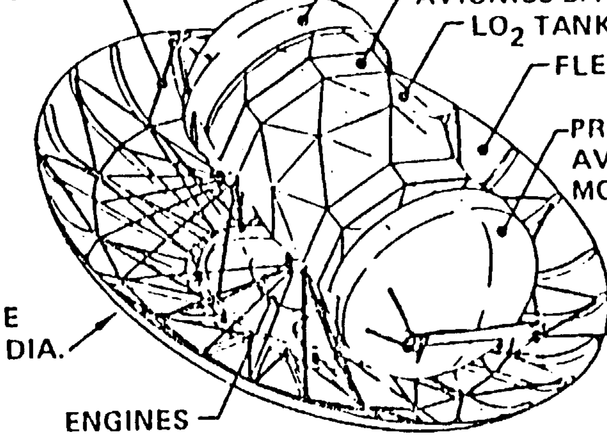
# SB OTV Lifting Brake Concept Configuration Trade

OTV-725

MIDTERM CONCEPT

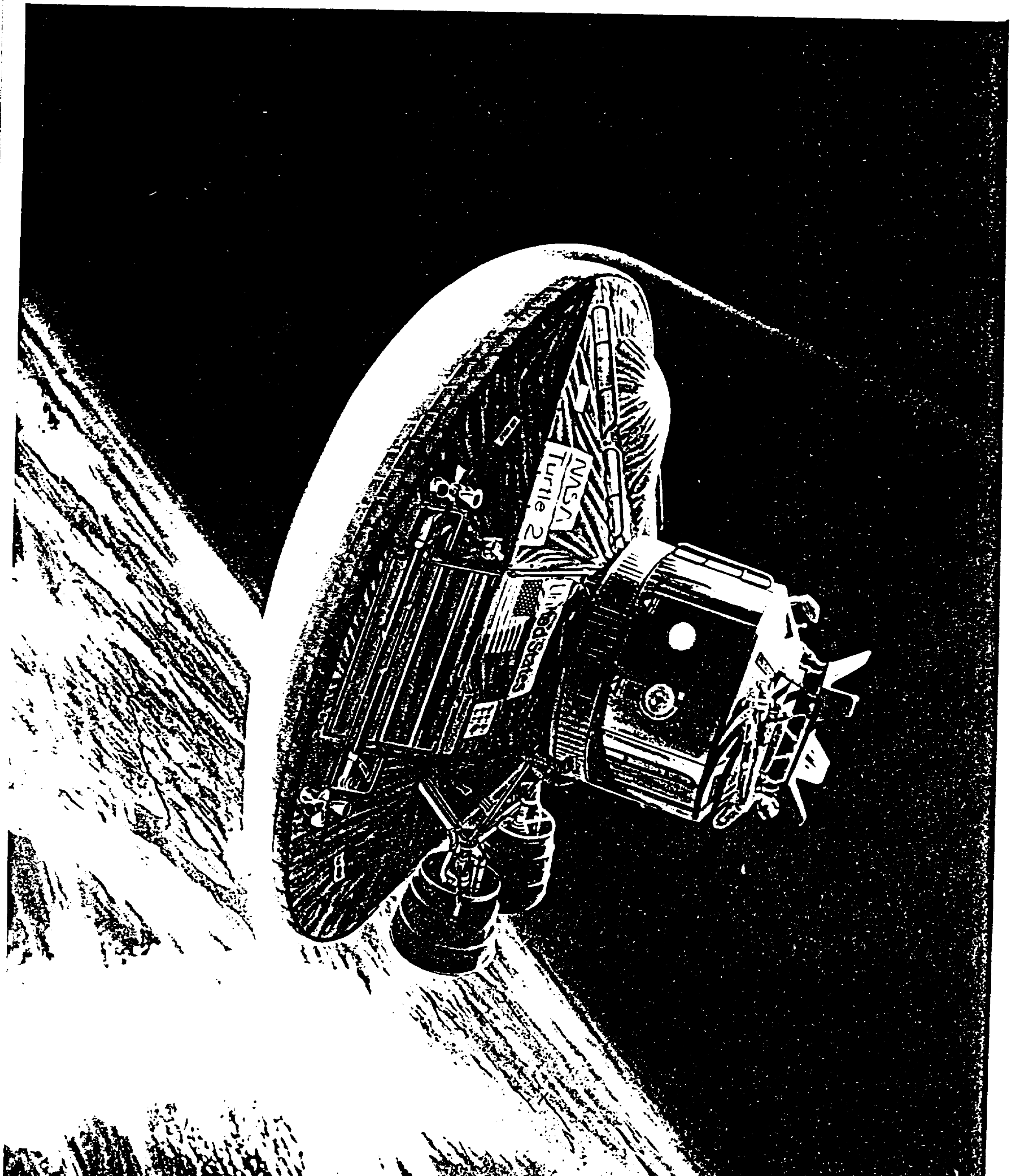



THIRD QUARTER CONCEPT




| MIDTERM CONCEPT | KEY CHANGES | THIRD QUARTER CONCEPT |
|---|---|---|
| • 6–7 ($O_2$ TANKS; ENGINES; BRAKE; TPS; AVIONICS) | • MAJOR ORBITAL ASSEMBLIES | • 3–4 (PROP TANK/AVIONICS; BRAKE; TPS; ENGINES) |
| • 11.0 | • $W/C_DA$ | • 10.3 |
| • 4 | • NUMBER FLUID/ELECTRICAL CONNECTION | • 2 |
| • CENTRAL BODY TRUSS STRUCTURE WITH SPHERICAL PROP TANKS | • STRUCTURE | • STRUT-SUPPORTED ELLIPTICAL-DOME TANK ASSEMBLY |
| • TPS SIZED ASSUMING FULL BACKWALL RADIATION (1150) | • TPS WEIGHT | • INCREASED TPS THICKNESS (1607) |
| • 1976 | • BRAKE STRUCTURE WEIGHT | • 1670 |
| • 60,000 | • USABLE PROP. LOAD | • 66,500 |
| • 9285 | • DRY WEIGHT | • 9947 |

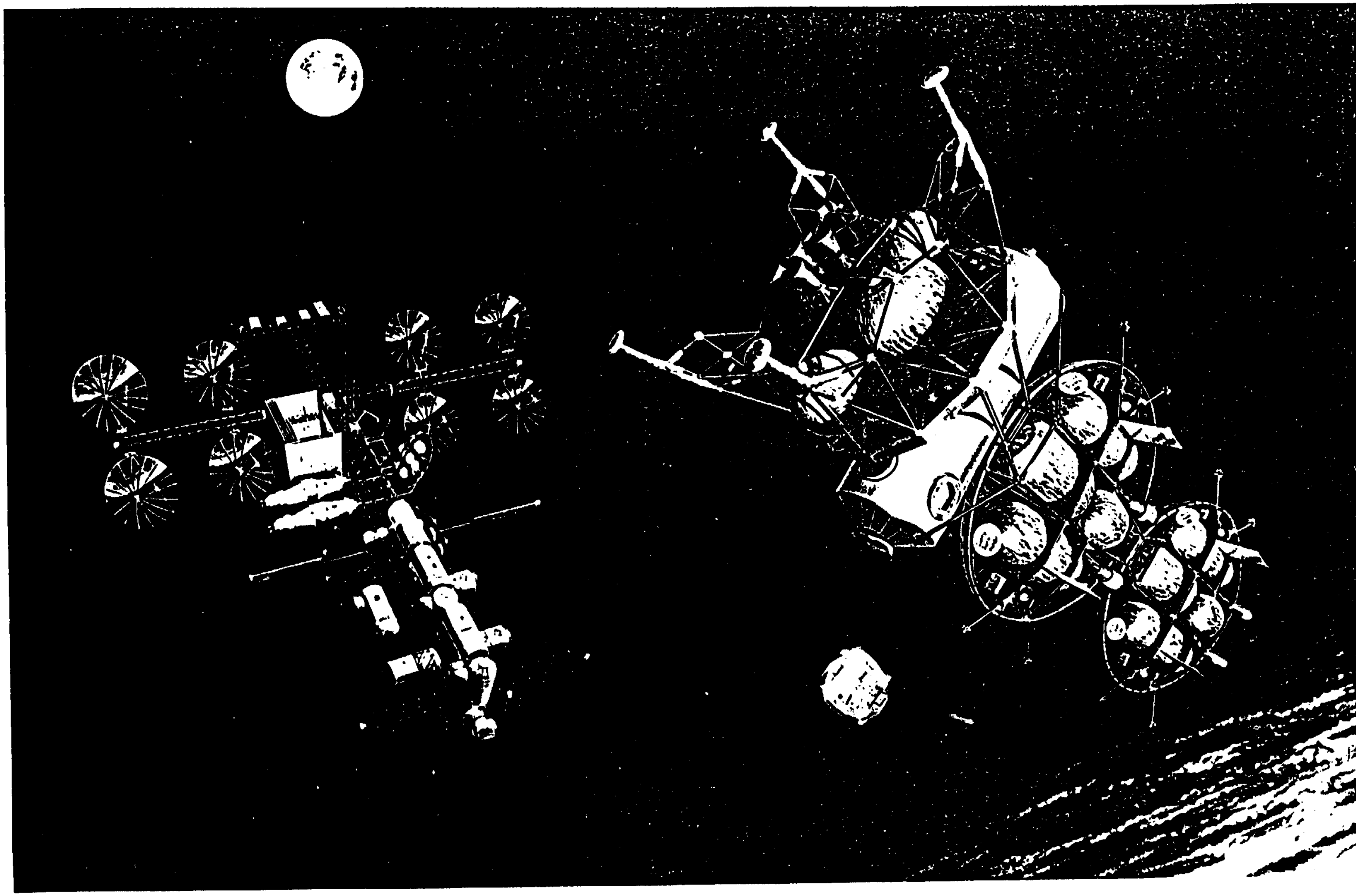
BOEING

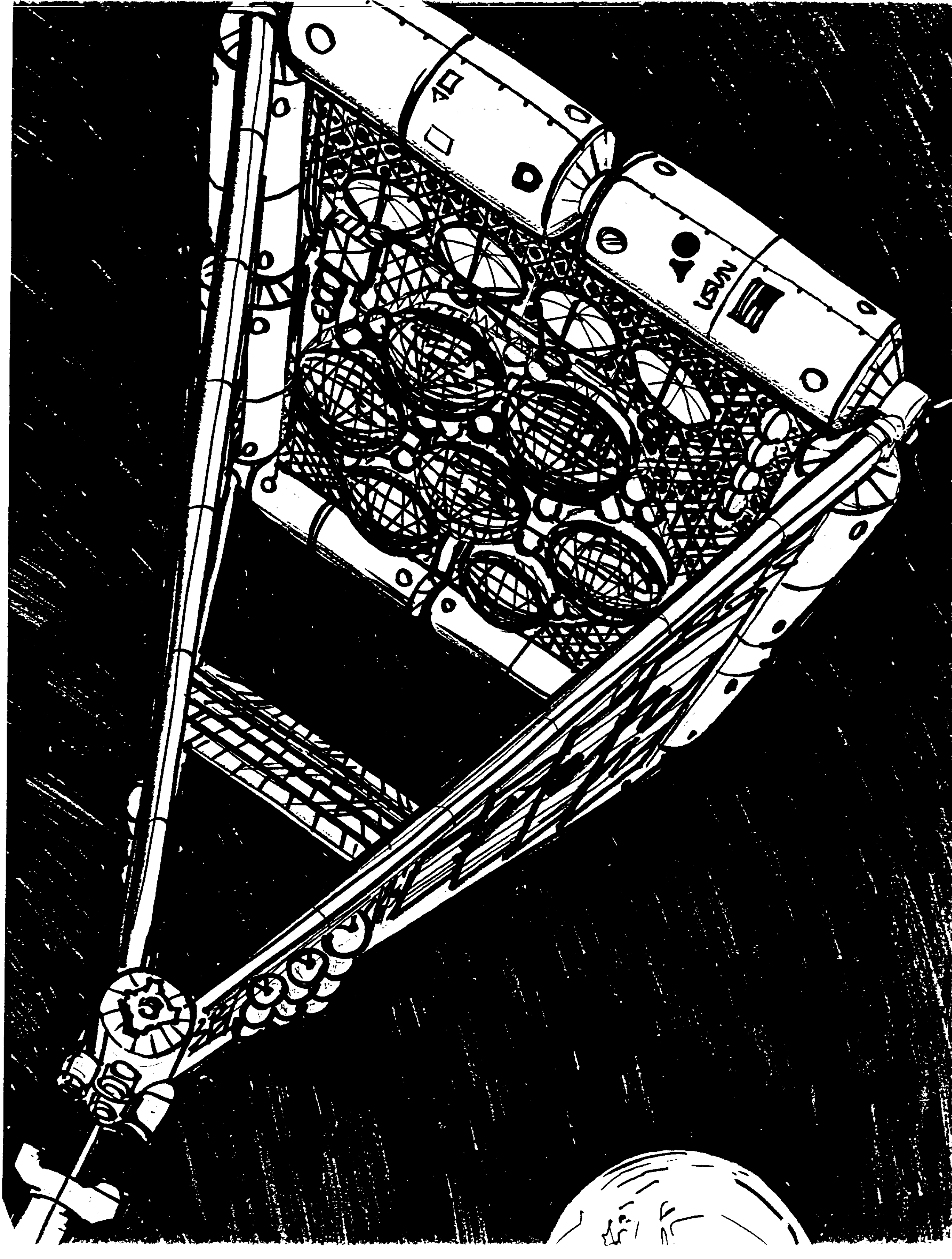

NASA
Turtle 2

National Aeronautics and Space Administration

S84-43854

Lyndon B. Johnson Space Center
Houston, Texas 77058




NASA